ISSN: 0001-5113 AADRAY	ACTA ADRIAT., 55(1): 85 - 100, 2014	ORIGINAL RESEARCH PAPER

Life cycle traits and stock assessment of *Pegusa impar* (Bennett, 1831) in the shallow coastal waters of Southwest Sicily

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From spring 2002 to winter 2011 a catch-effort survey was conducted in the wide Gulf between Cape San Marco and Cape Granitola (southwest coast of Sicily). The target fleet was the small scale fishery, using trammel net and gill net, based in the port of Marinella di Selinunte located in the centre of the Gulf. From 2005 to 2008 seasonal statistically significant samples of the catch of Pegusa impar *(BENNETT, 1831) Adriatic sole were purchased to study the life history. The growth parameters of the Von Bertanlaffy model were estimated: L_∞ = 249 mm, k = 0.25 year^{-1}, t_0 = - 2.0 year for females; L_∞ = 250 mm, k = 0.26 year^{-1}, t_0 = - 1.8 year for males. The maximum estimated age by whole otolith was 6 + years old. The parameters a and b of the length-weight relationship were estimated a = 0.000007 and b = 3.0562 for females and a = 0.000008 and b = 3.0157 for males. Length at first sexual maturity was 155.82 mm and 156.22 mm for females and males respectively. Age at first sexual maturity was 1.99 years for females and 2.57 years for males. The spawning period lasts throughout spring and summer with a migration from greater depths into shallow waters. The most exploited length class was 160 mm through 2007 but in 2008 it became 150 mm. The yearly catch ranged from 842 Kg and 9,743 specimens to 2,703 Kg and 65,345 specimens. The annual fishing effort ranged from 3,142 Km of gear at sea to 6,017 Km of gear at sea. Stock assessment was carried out in the frame of the Schaefer model using FMSP-CEDA software. The Maximum Sustainable Yield, the Carrying capacity, the Catchability coefficient, the Intrinsic population growth rate and the Replacement yield were respectively 2,140 kg, 7,132 kg, 0.000055 kg, 1.200 and 1,869 kg. The biomass trend predicted to 2020 shows that if after 2011 fishing effort increases by ten percent year by year, the resource will begin to decline beginning in 2013. Although the present data do not indicate that the resource is currently in overexploitation, it is however necessary not to increase fishing effort.*

Key words: *Pegusa impar*; artisanal fishery; life cycle; stock assessment; Mediterranean Sea.

INTRODUCTION

The flatfish Adriatic sole, *Pegusa impar*, is a Pleuronectiformes with a very wide distribution in shallow waters throughout the entire Mediterranean Sea as well as the eastern Atlantic coast from Gibraltar to Senegal. It lives in coastal marine environments on gravel, sand and muddy sand and its bathymetric distribution extends from about 30 to 100 m (WHITEHEAD *et al*., 1986) Although along the southwest coast of Sicily Adriatic sole is more commonly found in shallow waters from 5 to 30 m.

Morphologically it is characterized by an anterior nasal tube on the blind side greatly enlarged with radial septa. The colour is varying tonalities of brown often with spotting and/or dark spots. The pectoral fin has a black spot on the right that does not extend to the edge (BORSA *et al.,* 2001; VITALE *et al.,* 2004). Not much is known about the biology or catches of *Pegusa impar*. The primary objective of this work is the study of the life cycle, catches, fishing effort and stock assessment of *Pegusa impar* (Adriatic sole) in the shallow coastal waters of Marinella di Selinunte (southwest coast of Sicily). This small port, located in the middle of the wide gulf reaching from Cape San Marco to the east to Cape Granitola to the west, is home to an artisanal fleet composed of about 35 fishing boats in winter, and as many as 45 or more in summer. All the fishing vessels, which are registered in the Harbour Master's Office at Mazara del Vallo, are grouped together in a small, poorly-equipped port that is often made impracticable by stormy seas. Almost all the fishermen are organised into a single co-operative that sells practically the entire catch in a typical auction which is open to the public. In the last ten years the average catch of *Pegusa impar* during spring and summer was about 7% of the total catch.

For this reason from the early 1990s, Marinella di Selinunte and its coastline were chosen as an experimental field and bio-ecologic laboratory dedicated to the assessment and management of fishing resources of the shallow coastal waters and to the study of Fishery Science from a bio-economic standpoint (CANNIZZARO *et al*., 2011).

MATERIAL AND METHODS

Study area and data collection

The study area is the wide gulf located along the southwest coast of Sicily between Cape San Marco to the east and Cape Granitola to the west and isobath of 50 m (Fig. 1). It comprises a strip of sea of about 250 km^2 including the mouth of the Belice River and of various other rivers of torrential character (Modione, Carboi, Cavarritto) that provide fine-grained terrigenous material.

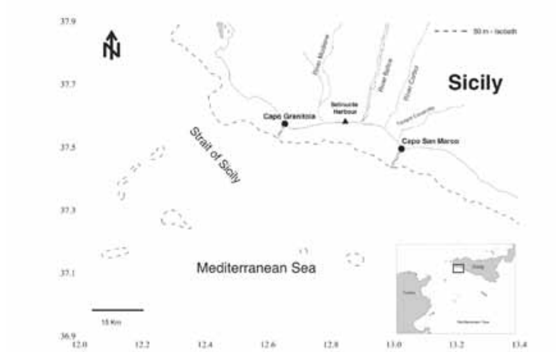

Fig. 1. Study area

The area is also characterized by strong upwelling and cold currents (GARCIA LAFUENTE *et al*., 2002) with the summer and winter water mean temperatures (at depths < 20 m) of 17 °C and 14 °C, respectively (PICCO, 1990).

Marinella di Selinunte is a small port located in the middle of this wide gulf and is home to an artisanal fleet that works, with only rare seasonal exceptions, exclusively with trammel nets and gill nets along the coastline and at a depth not greater than 50 m. The fishing areas are heterogeneous and include various types of seabed: sandy (40%), muddy (20%), rocky (20%) and a large area of sea-grass (20%).

In the scope of a series of projects begun in April of 2002 and still in course today, landing interviews are performed to monitor the catch and fishing effort of the artisanal fleet that is based at Marinella di Selinunte. Initially, a frame survey was made of all fishing boats in port, of the fishing equipment used and of the fishing areas habitually frequented. The census is updated at the beginning of each season. The statistical design of the monitoring in space and time was refined and optimized during a previous catch effort survey (CANNIZZARO *et al.,* 2000) so that from spring 2002 one day of interviews was conducted for every eight days, including holidays. On each interview day, the interviewers arrive at the port before the boats return from fishing so as to count the inactive boats. As the boats begin to arrive in port the interviewers, of whom there are always at least two, count all the crates of fish that are unloaded, identify all the species unloaded and interview the fishermen to ascertain: the quantity in meters of trammel net and gill net put to sea, the fishing area, at what time the nets were cast and at what time they were brought in.

Moreover, between October 1997 and September 2008, 36 fishing experiments were carried out with trammel net and gill net to evaluate the credibility of the interviews and discards. In the case of *Pegusa impar* discards do not exist, therefore for this species the quantities unloaded coincide with the catches and in the present work the words unloaded and catch are used interchangeably.

The minimum number of interviews conducted on each sampling day is 25% of the fishing boats active on that day (CANNIZZARO *et al*., 2009). From 2005 to 2008 monthly samples of the catch of Adriatic sole were purchased in order to study the population structure and life cycle. Practically all specimens of *Pegusa impar* caught by a particular fishing vessel, previously chosen at random and without the fisherman's knowledge, were purchased every month (CANNIZZARO *et al.,* 2000).

Data elaboration and analysis

Biometric and biological data of all samples were collected. Total length (TL, mm), somatic weight (W, to the nearest 1 g) and total gonad weight (to the nearest 0.01 g) were measured for each specimen. Sex determination and maturity stage were assigned by macroscopic examination of the gonads. Catch structures were constructed for each year. The stages of maturation were classified according to the five-grade maturity scale of HOLDEN & RAITT (1974).

Sagittal otoliths pairs were removed, cleaned and stored in dry boxes. Age was estimated from whole otoliths. Sagittal otoliths were examined in a black Petri dish containing 96% ethyl alcohol under reflected light using a dissecting microscope at 12x magnification. Aging criteria were the same compared to that reported in (VITALE *et al*., 2011a) assuming that a single annual growth increment consists of an opaque and a translucent zone.

The growth parameters L_∞, K and t_0 of the von Bertalanffy model were estimated by otolith readings.

The growth performance index (Φ) was calculated (PAULY & MUNRO, 1984).

Length–weight relationships ($W = aL^b$) were estimated for each sex and year (ANDERSON & NEUMANN, 1996).

All the above mentioned parameters were estimated through non-linear adaptation to the mathematic model of the experimental data. The a and b and the growth parameters were compared from other authors.

The reproductive period was established taking into consideration the temporal frequency of maturity stages, and the monthly values of the gonad somatic index (GSI) (ANDERSON & GUTREUTER, 1983).

The size-at-first maturity (length at which 50% of the individuals in the population are mature) was estimated using specimens collected during the spawning period. A logistic curve was fitted using the least-squares method applied to a non-linear fit (KING, 1995). The overall sex ratio and the sex ratios by size (10 mm) and age intervals (0.5 years) were also determined.

Total catch of *Pegusa impar* and the relative fishing effort per season and per year were estimated from sample data (landing interviews) using classic statistical methods according to the following formulas:

$$c_m = \sum_{i=1}^{I} c_i / I; \quad i = 1, 2, \ldots, I$$

Variance will be:

$$\mathrm{Var}(c_m) = \sum_{i=1}^{I} (c_i - c_m)^2 / (I - 1); \quad i = 1, 2, \ldots, I$$

where c_m is the average catch per boat per day; c_i is the catch of the i-th fishing vessel interviewed; I are the total number of interviews in the period considered (month, season, year).

Total catch in the reference period will be:

$$C_t = (N_{ba}/I)(G_p/g_I) \sum_{i=1}^{I} c_i \; ; \; i = 1, 2, \ldots, I$$

The variance will be given by:

$$VAR(C_t) = (N_{ba}/I)^2(G_p/g_I)^2 \, Var(c_m);$$

where C_t is the total catch in the reference period; N_{ba} is the number of active fishing vessels in the reference period; G_p and g_I are, respectively, the total number of available fishing days and the number of interview days in the reference period. Fishing effort was defined as: length in kilometers of the nets (trammel net and gill net) put into the sea by all boats active on each fishing day. So the effort in a fishing day was: e = N_{ba} x average Km of net put to sea; where N_{ba} was the fishing capacity and the average Km of net put to sea the activity.

Mathematically the effort was treated with the same formulation used for the catch as reported above:

$$e_m = \sum_{i=1}^{I} e_i / I \; ; \quad i = 1, 2, \ldots, I$$

The variance will be:

$$Var(e_m) = \sum_{i=1}^{I} (e_i - e_m)^2 / (I - 1); \quad i = 1, 2, \ldots, I$$

where e_m is the average effort per fishing vessel per day; e_i is the effort of the i-th fishing vessel interviewed.

Total effort in the reference period will be:

$$E_t = (N_{ba}/I)(G_p/g_I) \sum_{i=1}^{I} e_i \; ; \; i = 1, 2, \ldots, I$$

Variance will be given as:

$$VAR(E_t) = (N_{ba}/I)^2(G_p/g_I)^2 \, Var(e_m);$$

where E_t is the total effort in the reference period (CANNIZZARO *et al.*, 2011).

The catch per unit of effort (cpue) was calculated as the relationship between the total catch in the reference period and the fishing effort in the same period.

The Maximum Sustainable Yield (MSY), the Carrying capacity (K), the Catchability coefficient (q), the Intrinsic population growth rate (r) and the Replacement yield (R Yield) were estimated by the Schaefer model using the Fisheries Management Science Programme - Catch and Effort Data Analysis (FMSP-CEDA) software (HOGGARTH *et al.*, 2006). Moreover, the Biomass trend through 2020 was predicted using the mentioned software to hypothesize two different scenarios. Under the first scenario the hypothesis is that fishing effort until 2015 will be similar to the effort of the last 3 years. Therefore four effort values were randomly selected between 5000 and 6000. The hypothesis is that from 2016 until 2020 the effort will increase until reaching values between 6000 and 7000. So another five effort values were randomly selected between the last mentioned period. In the second scenario the hypothesis is that effort beginning in 2011-12 increases by ten percent each year. The 50% confidences intervals were calculated for all estimated values and for all scenarios by the bootstrap method. In addition, fishing effort that produces the MSY (f_{MSY}), the fishing mortality at MSY (F_{MSY}) and Biomass were calculated.

RESULTS

The histograms of Fig. 2 show the structure for size of fish caught in the years 2005, 2006, 2007 and 2008. The dashed line represents the size at first sexual maturity. The most exploited length class was 160 mm in 2005, 2006 and 2007, and 150 mm in 2008. The minimum size captured was 120 mm from 2005 until 2007 and 130 mm in 2008; the maximum size was 210 mm in 2005, 230 mm in 2006, 200 mm in 2007 and 230 mm in 2008.

Overall sex ratio, growth parameters, length at first maturity and the parameters of the length-weight relationship are reported in Table 1.

The patterns of opaque and translucent zones on whole otoliths were clearly identifiable. The maximum estimated age by whole otolith was 6 + years old. The growth parameters did not show significant differences between males and females with a k value of 0.25 for males and 0.26 for females. The estimate of the asymptotic length (L_∞) year^{-1} is almost identical differing by just 1 mm between males and females.

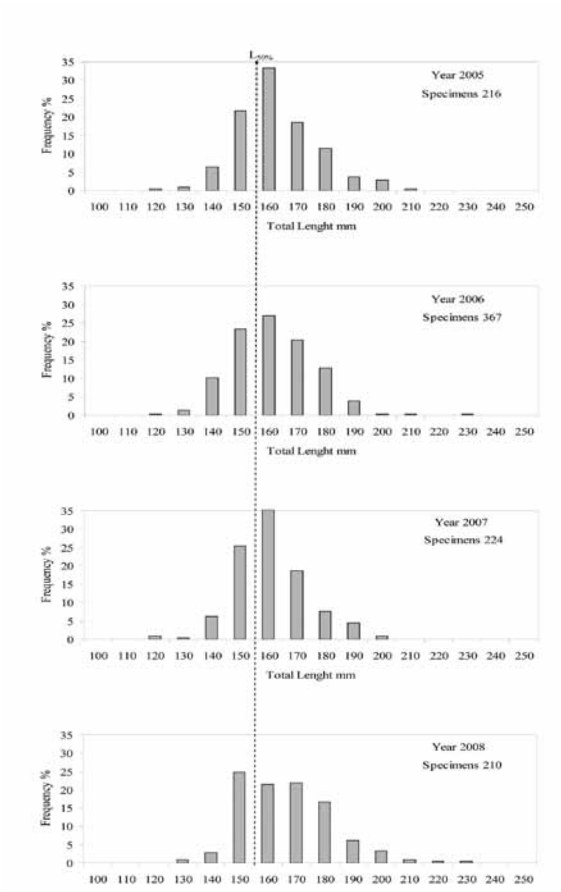

Fig. 2. Length frequency in the years 2005-2008 and length at first sexual maturity (dashed line)

The length-weight relationship for males and females together shows a positive allometric relationship. However, this allometry decreases dramatically when one considers the relationship for females and males separately. The values of the coefficients of adaptability of the model show a good fit to the experimental data.

The size at first sexual maturity was 155.82 mm for females and 156.22 for males. The age at first sexual maturity was 1.99 years and 2.57 years for females and males, respectively.

Table 2 shows the average total length and its coefficient of variation (CV) per year in spring and summer. The average lengths in the summer are a bit lower than the spring.

Table 3 shows the average somatic weight and its CV per year in the spring and summer, similar to the average size the average somatic weight in summer is lower than in spring. The coefficients of variation were significantly higher than those found in the case of the average size.

The gonad somatic index (Fig. 3) in females reaches the maximum in April and then gradually decreases to almost zero in September. In males the GSI shows the same maximum in

Table 1. Overall sex ratio, growth parameters, length-weight relationship parameters, length and age at first sexual maturity, number of specimens examined, and coefficient of adaptability

	Sexes combined	Female	Male
		Overall sex ratio	
n	510	242 (47%)	268 (53%)
		Von Bertalanffy growth parameters	
n	950	242	240
L_∞	260 mm	249 mm	250 mm
k	0.26 $year^{-1}$	0.25 $year^{-1}$	0.26 $year^{-1}$
t_0	- 1.5 year	- 2.0 year	- 1.8 year
Φ	4.24	4.19	4.21
R^2	0.71	0.70	0.69
		Length-Weight relationship parameters ($W=aL^b$)	
n	1017	242	268
a	0.000003	0.000007	0.000008
b	3.1894	3.0562	3.0157
R^2	0.8035	0.889	0.8123
		First sexual maturity	
n		242	256
$L_{50\%}$		155.82 mm	156.22 mm
$A_{50\%}$		1.99 year	2.57 year

Table 2. Average length per year in spring and summer with CV

Season	N°	Average Length mm	CV	Season	N°	Average Length mm	CV
Spring 2005	112	165	9 %	Summer 2005	104	159	9 %
Spring 2006	223	162	8 %	Summer 2006	144	159	9 %
Spring 2007	108	165	8 %	Summer 2007	116	156	8 %
Spring 2008	135	165	9 %	Summer 2008	65	164	8 %

Table 3. Average somatic weight per year in spring and summer with CV

Season	N°	Average Weight g	CV	Season	N°	Average Weight g	CV
Spring 2005	112	43	37 %	Summer 2005	104	38	32 %
Spring 2006	223	38	30 %	Summer 2006	144	37	33 %
Spring 2007	108	38	32 %	Summer 2007	116	34	26 %
Spring 2008	135	42	35 %	Summer 2008	65	44	26 %

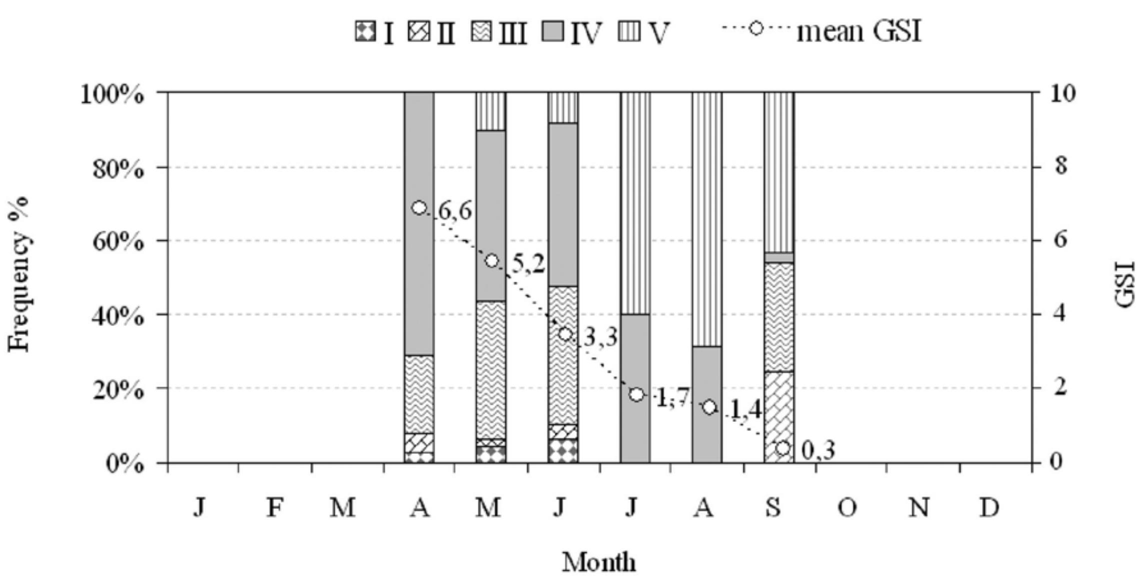

Fig. 3. Frequency per month of maturity stage and mean of GSI per month

April, but already from May to September the GSI stabilizes around a mean value which is approximately half of the maximum in April. The spawning period was mainly in spring and it is extended to September.

The sex ratio for size classes (Fig. 4 a) shows that with increasing length the percentage of females increases, reaching 50% at about 160 mm in total length, and grows until it reaches 100% at 200 mm in total length. Similarly, the sex ratio in the age classes (Fig. 4 b) is result of 1:1 between 1.5 and 2 years of age but with increasing age the percentage of female specimens increases until reaching 100% at 4.5 years old.

The fleet at Selinunte is comprised of small vessels suited to fishing exclusively along the coast. Even if most of the boats are able to fish up to 6 miles from the coast, they are unlikely to operate beyond 3 miles. It is a moderately old fleet with an average age of 40 years; the newest boat is 18 years old, the oldest over 70.

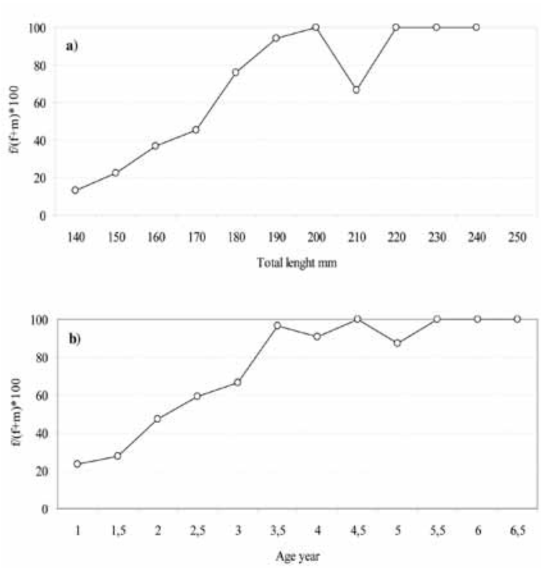

Fig. 4. Sex ratio by length and by age classes

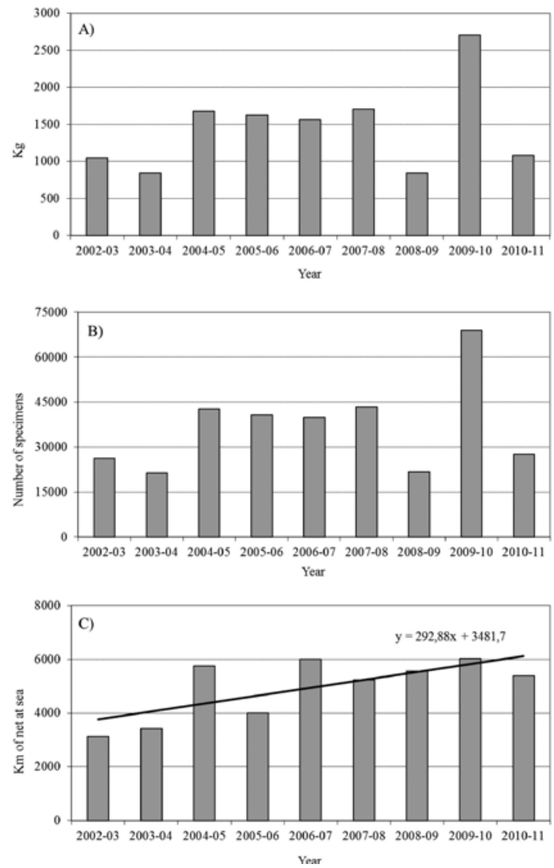

Fig. 5. Yield per year, number of specimens caught per year and effort per year

In the last year the mean length of the boats was 6.5 m and the average power of the motors about 20 Kw. The fleet exploited the entire study area, single fishing areas are contiguous and cover the entire study area. The fishermen have given names to each fishing area which are generally linked to the nature of the seabed. It is a typically artisanal fleet, the crew is generally comprised of a single and, except in rare cases, elderly fisherman. The entire catch is packed in one kilogram crates and sold at a typical auction which is open to the public. Even though the auction maximizes the value of the catch, often the most prized species are sold directly to local restaurants (CANNIZZARO *et al.,* 2011). Table

Table 4. Number of boats based at Marinella di Selinunte and fishing gear employed

Year	Number of Boats	Trammel net	Multiple Gear: Trammel net and Gill net
		FAO 750	FAO 9000
2002	37	49 %	51 %
2003	41	44 %	56 %
2004	41	44 %	56 %
2005	37	38 %	62 %
2006	39	31 %	64 %
2007	39	31 %	64 %
2008	35	23 %	77 %
2009	36	22 %	78 %
2010	34	18 %	82 %
2011	35	17 %	83 %

Table 5. Total yield in kg, number of specimens caught, effort in km of trammel net and/or gill net at sea and related standard errors and cpue

Period	Total yield Kg	Standard error Kg	Number of specimens caught	Standard error number	Effort Km of gear at sea	Standard error Km	cpue Kg/Km	cpue sp./Km
Spring 2002	650	15	16,149	382	1,357	9	0.479	12
Summer 2002	253	14	6,617	364	1,433	13	0.177	5
Fall 2002	16	5	421	133	187	3	0.086	2
Winter 2003	62	7	1,551	174	283	6	0.220	5
Year 2002-03	**1,048**	**15**	**26,271**	**375**	**3,142**	**9**	**0.334**	**8**
Spring 2003	285	15	7,071	382	530	9	0.537	13
Summer 2003	417	27	10,889	706	1,052	14	0.396	10
Fall 2003	62	4	1,633	107	851	9	0.073	2
Winter 2004	120	8	2,971	211	1,033	13	0.116	3
Year 2003-04	**842**	**15**	**21,473**	**389**	**3,443**	**11**	**0.245**	**6**
Spring 2004	788	18	19,579	443	2,233	15	0.353	9
Summer 2004	757	29	19,783	771	2,155	7	0.351	9
Fall 2004	48	13	1,245	345	695	14	0.068	2
Winter 2005	34	12	839	296	770	5	0.044	1
Year 2004-05	**1,676**	**23**	**42,664**	**579**	**5,738**	**15**	**0.292**	**7**
Spring 2005	1,440	31	35,773	772	2,523	8	0.571	14
Summer 2005	221	31	5,788	819	655	4	0.338	9
Fall 2005	10	3	273	79	596	4	0.018	0.5
Winter 2006	16	6	407	144	281	5	0.058	1
Year 2005-06	**1,629**	**29**	**40,687**	**717**	**3,997**	**8**	**0.408**	**10**
Spring 2006	721	17	17,902	412	1,765	4	0.408	10
Summer 2006	889	23	23,232	610	2,697	5	0.329	9
Fall 2006	0	0	0	0	833	2	0.000	0
Winter 2007	66	7	1,644	177	1,637	4	0.040	1
Year 2006-07	**1,567**	**17**	**39,876**	**442**	**6,012**	**5**	**0.261**	**7**
Spring 2007	973	37	24,171	914	1,646	5	0.591	15
Summer 2007	753	29	19,698	755	2,216	4	0.340	9
Fall 2007	0	0	0	0	115	2	0.000	0
Winter 2008	76	7	1,894	185	1,182	4	0.065	2
Year 2007-08	**1,708**	**28**	**43,427**	**719**	**5,230**	**4**	**0.327**	**8**
Spring 2008	152	11	3,788	266	1,634	4	0.093	2
Summer 2008	639	23	16,702	598	2,397	4	0.267	7
Fall 2008	0	0	0	0	513	3	0.000	0
Winter 2009	41	14	1,016	359	936	4	0.044	1
Year 2008-09	**844**	**18**	**21,812**	**475**	**5,557**	**4**	**0.152**	**4**
Spring 2009	1,378	28	34,227	692	2,709	3	0.508	13
Summer 2009	1,407	32	36,786	830	2,368	3	0.594	16
Fall 2009	75	8	1,960	201	542	2	0.138	4
Winter 2010	0	0	0	0	384	2	0.000	0
Year 2009-10	**2,703**	**26**	**68,939**	**665**	**6,017**	**3**	**0.449**	**11**
Spring 2010	412	19	10,236	463	1,226	3	0.336	8
Summer 2010	657	20	17,171	517	2,536	3	0.259	7
Fall 2010	20	3	528	86	521	2	0.039	1
Winter 2011	70	7	1,738	172	992	3	0.071	2
Year 2010-11	**1080**	**15**	**27,625**	**396**	**5,382**	**3**	**0.201**	**5**

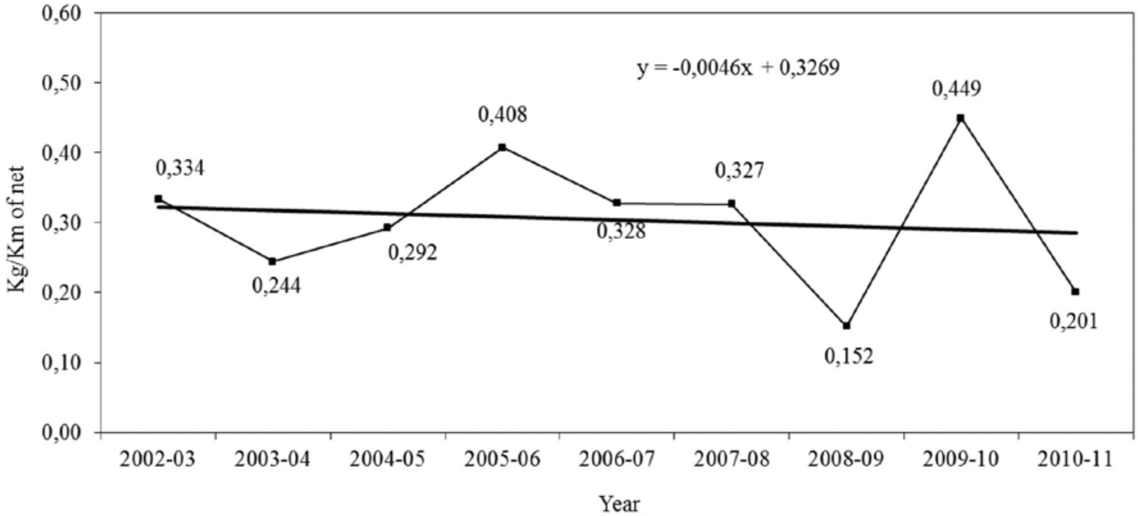

Fig. 6. Cpue in weight per year and cpue trend

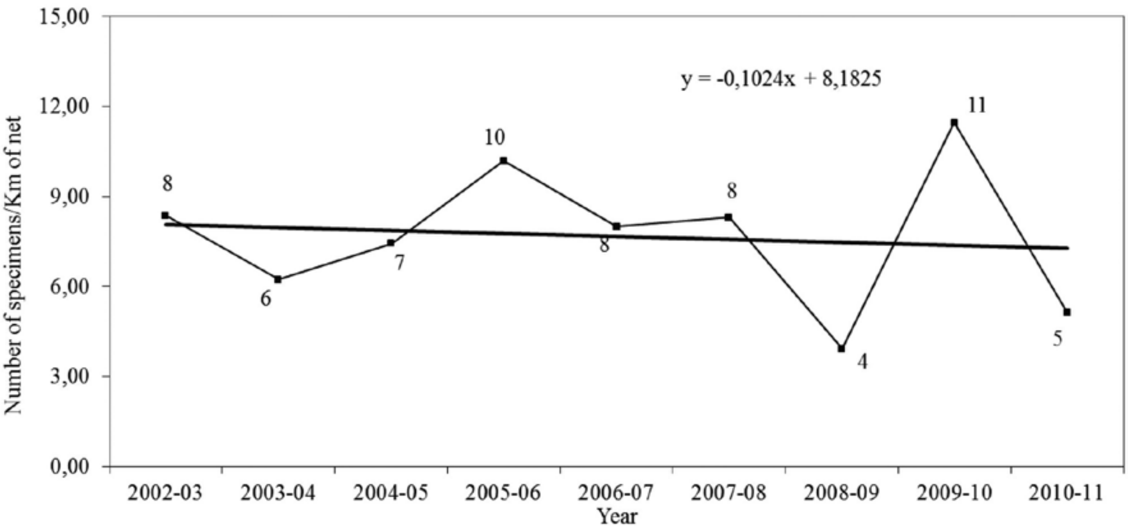

Fig. 7. Cpue in number of specimens caught per year and cpue trend

4 shows boats from the artisanal fleet based at Marinella di Selinunte that use trammel nets (code FAO 750) and multiple gear (trammel nets and gill nets; code FAO 9000; see NÉDÉLEC & PRADO, 1990). The fishermen of Marinella di Selinunte use trammel nets on sandy or muddy seabeds, and gill net on rocky seabed. Trammel net is made with three walls of netting with a height of between 2.5 and 3.5 meters. The inner netting panel presents fine mesh with a dimension between 30 and 40 mm (mesh size), while the two outer walls are of a larger mesh (150 to 250 mm mesh size). The gill net differs from the net described above in the absence of the outer walls and in its mesh dimension (normally finer than the inner netting panel of trammel nets) (CANNIZZARO *et al.,* 2000).

Table 5 shows the total yield, number of specimens caught, effort in km of trammel net and/or gill net at sea and related standard errors and the cpue in weight and in number of specimens per kilometre of trammel net and/or gill net at sea.

The maximum catches are always made in spring and summer. Catches in the fall and winter are much smaller and sometimes zero, only

Table 6. Maximum Sustainable Yield, Carrying Capacity, Coefficient of Catchability, Intrinsic Growth Rate, Replacement Yield and related 50 % Confidence Interval

Esimated parameters	Lower limit	Value	Upper limit
MSY	1,228 Kg	2,140 Kg	5,154 Kg
K	3,960 Kg	7,132 Kg	16,478 Kg
q	0.0000093	0.000055	0.00011
r	0.853 Kg	1.200 Kg	1.590 Kg
R Yield	1,286 Kg	1,869 Kg	4,557 Kg

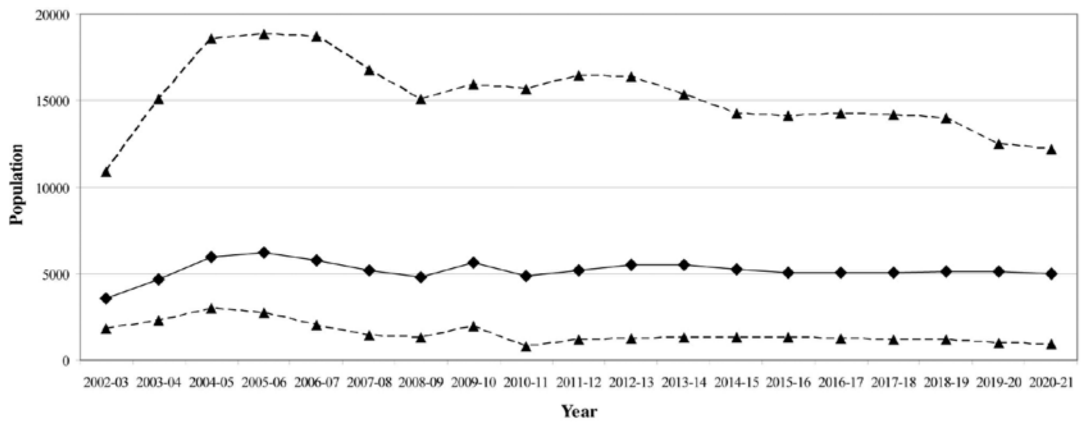

Fig. 8. Population per year until 2020 and 50 % confidence interval (scenario one)

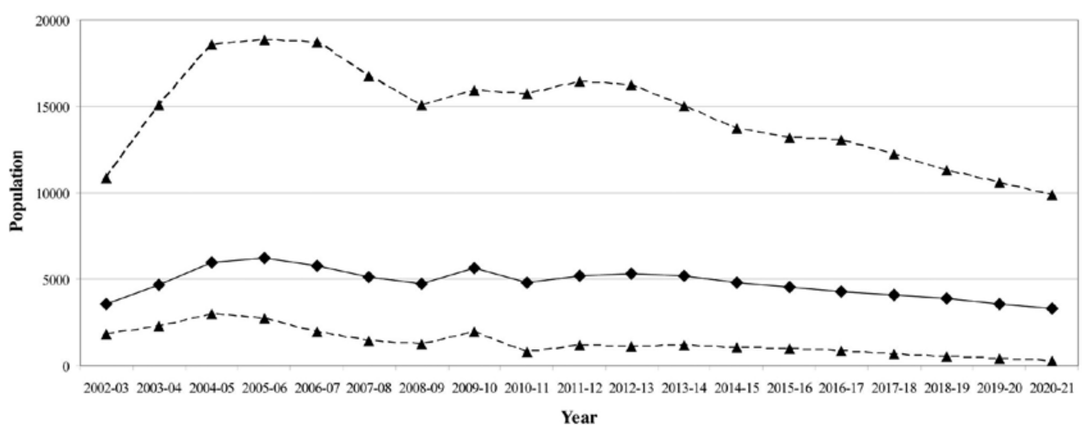

Fig. 9. Population per year until 2020 and 50 % confidence interval (scenario tow)

in the winter of 2004 did they reach 120 kg.

Fig. 5 shows the yield per year, the numbers of specimens caught per year, the fishing effort per year and the fishing effort trend. The maximum captures both by weight and by number of specimens were obtained in the year 2009-2010 while the minimum was carried out in the years 2003-04 and 2008-09.

The maximum allowable fishing effort was recorded in 2009-10. Despite the decrease of the number of vessels the trend of fishing effort is growing (Fig. 5 c).

From 2002 to 2007 the cpue in weight (Fig. 6) ranges from 0.244 kg/km to 0.408 kg/km, while in the following three years it ranges from 0.152 kg/km to 0.449 kg/km.

The cpue in number of fish per km of net at sea (Fig. 7) obviously follows the same trend as

Table 7. Parameters of Von Bertalanffy growth curve in the Bay of Douarnenez (Brittany) and in the southwest coast of Sicily

Author	L_∞	k	t_0	Φ	R^2	Range Length cm	Type	N°	Sex	Country	Locality
Deniel (1990)	29.1	0.546	0.162	2.66	-	18.0 – 34.0	TL	656	female	France	Brittany
Deniel (1990)	27.0	0.560	0.112	2.61	-	16.0 – 32.0	TL	559	male	France	Brittany
Present work	26.0	0.26	- 1.5	2.24	0.71	11.7 – 23.1	TL	950	Sex com.	Italy	SW Sicily
Present work	24.9	0.25	- 2.0	2.19	0.70	13.2 – 23.1	TL	242	female	Italy	SW Sicily
Present work	25.0	0.26	- 1.8	2.21	0.69	12.5 – 20.7	TL	240	male	Italy	SW Sicily

the cpue by weight; between 2002 and 2007 it varies between 6 and 10 specimens per km of net at sea while in the final three years of monitoring it varies between 4 and 11 specimens per km of net at sea. The trend can be defined as stable.

Table 6 shows the estimated: Maximum Sustainable Yield (MSY), Carrying Capacity (K), Coefficient of Catchability (q), Intrinsic Growth Rate (r), Replacement Yield (RYield) and related 50 % Confidence Interval; of the Schaefer production model on the hypothesis that the initial proportion was 0.5. The f_{MSY} and the F_{MSY} resulted respectively 10,909 and 0.600. The biomass at the MSY (B_{MSY}) was 3,566 kg and the final biomass was 5,169 kg.

Fig. 8 shows the population per year and the related 50 % confidence interval until 2020 in the case of the first scenario (the effort remains similar to the effort of the last three years until 2014-2015 after which it increases casually to between 6,000 and 7,000). The population remains constant at about 5,000 Kg.

Fig. 9 shows the second scenario (with effort increasing by ten percent each year) the population after 2012-13 decreases progressively until reaching about 3,000 Kg in 2020.

DISCUSSION

The most exploited length class, i.e. the length class that contributes most to the catch, can be determined from length frequency distributions and it resulted from 2005 to 2007 equal to 160 mm, i.e. just above the size at first sexual maturity that is approximately 156 mm for both females and males. The most exploited length class in 2008 falls to 150 mm, i.e. below the size of first sexual maturity. This could be a warning bell announcing excessive fishing effort. The most exploited size (160 mm) in the three years 2005 to 2007 reported an increasing frequency of 25% until to about 35% in 2007. The frequency of the size immediately smaller (150 mm) has always been between 20% and 25%. Moreover, the minimum size captured in the

Table 8. Parameters of length-weight relationship in the northern Adriatic sea and in the southwest coast of Sicily

Author	a	b	R^2	Range Length cm	Type	N°	Sex	Country	Locality
Dulcic *et al.* (2006)	0.0834	2.750	-	25.1 – 30.3	TL	12	unsexed	Croatia	Northern Adriatic
Present work	0.000003	3.1894	0.804	11.7 – 23.1	TL	1018	unsexed	Italy	SW Sicily
Present work	0.000007	3.0562	0.889	13.2 – 23.1	TL	241	female	Italy	SW Sicily
Present work	0.000008	3.0157	0.812	12.5 – 20.7	TL	268	male	Italy	SW Sicily

first three years of biological sampling was 120 mm while in the fourth year (2008) it was 130 mm. It would seem then, that in 2008 there may have been some problem with gear recruitment.

There were no significant differences in growth parameters or in the parameters of the length weight relationship of males and females.

Table 7 shows the parameters of the Von Bertalanffy growth curve estimated from DENIEL (1990) for *Pegusa impar* in the Bay of Douarnenez (Brittany) and those estimated in this paper. In the Bay of Douarnenez asymptotic length (L_{∞}) is larger and the growth rate is almost double those of the southwest coast of Sicily. The higher growth rate estimated by DENIEL (1990) seems to suggest that this species prefers the colder waters of the Bay of Douanenez to the warmer waters of the Strait of Sicily without taking into consideration other factors i.e. diet and food availability, fishing pressure as well as several oceanographic factors.

Table 8 shows the parameters of the length-weight relationship estimated from DULČIĆ *et al.* (2006) for the *Pegusa impar* in the north Adriatic Sea and those estimated in this paper.

The parameters a and b of the length-weight relationship in the northern Adriatic Sea are very different from those estimated for the southwest coast of Sicily probably because the Adriatic specimens are bigger that the Sicilian specimens. In fact, the range of lengths of the specimens from the Adriatic Sea is about 25 cm to 30 cm and the range of those in Sicily from about 12 cm to about 23 cm.

The average size and the average somatic weight by season (Tables 2 & 3) show that the largest specimens, i.e. the oldest specimens, come into the shallow coastal waters mainly in spring. Younger specimens and specimens at first sexual maturity arrive mainly in summer. Any eventual management measures must take these facts into account.

The species has a very prolonged spawning season that lasts from spring through late summer in agreement with DENIEL *et al.* (1989) for the same species along the western coast of Brittany.

The sex ratio shows that the balance between males and females is reached at a size between 170 mm and 180 mm. From 180 mm and up, the number of females begins to increase until reaching 100% at lengths greater than 200 mm. The analysis by age shows that the specimens aged between 2 and 2.5 years are 50% female. With increasing age the number of males decreases rapidly, and by age 4.5 years and greater all of the specimens are females. Since the growth parameters were essentially the same for males and females it seems reasonable to hypothesize hermaphroditism even though the simultaneous presence of male and female gonads has not been observed nor has asynchrony in migration from shallow waters to greater depths by males earlier than females. Further investigation by histological examinations of the gonads will be useful to support the first hypothesis.

As shown in Table 5, the species is caught mainly in spring and summer. During the fall and winter the species is caught in small quantities (a few specimens per vessel), therefore it is not sold in individual, monospecific boxes but together with other species of the same commercial value (usually small-medium sized Sparidae). It was therefore impossible to acquire representative samples of the catches of Adriatic sole in the fall and winter. It must also be taken into consideration that during the fall, Sicilian artisanal fishery is subjected to a fishing ban of 45 days. For this reason, and taking into account the days of adverse sea conditions and weather, the number of fishing days carried out during autumn are far fewer than those carried out during the other seasons. Therefore, the observed zero catches in autumn for some years may also be the result of chance.

In 2003-04 the yield and the specimens caught showed the lowest values of the entire study period amounting to 842 kg and 21,473 respectively. In 2008-09 the minimum values were the cpue in weight (0.152 kg/km) and the cpue in number of specimens (4 specimens/km). Despite the yield, the cpue in weight and the cpue in number of specimens in 2009-2010 reached the maximum of the whole period. The catches in winter 2010 were zero, this is likely due to the fact that on 11 days of interviews conducted in the winter of 2010, the actual fishing days were 3 with only 22 active boats.

So despite the fact that 55% of active boats were interviewed (12 interviews), the catch of Adriatic sole was zero only by pure chance. To overcome this possibility it would be necessary to increase the number of interview days. But to cover all days of the week interviews must be increased from one interview day in every eight days to one interview day every six days with an increase in costs of about 25% which at this time is unsustainable.

The trend in fishing effort is positive, despite the decrease in the number of boats (Table 4). The decommissioned vessels have ceded their fishing gear to active vessels so there was a significant decrease of the total capacity of fishing.

It seems that the resource responds to the increase of the fishing effort with large oscillations in both the cpue in weight and in number of fish. The trend of the cpue over the whole period is negative with a slope equal to - 0.0046 and - 0.1024 respectively for the cpue in weight and in number of specimens. However, between 2002 and 2009, the trend is positive, the slope of the two cpues were respectively 0.0033 and 0.0998. The drop in cpue observed in the last year caused a change in the sign of the slope so that the trend became negative. Regardless, since the slope is very near zero the resource seems to be stable with respect to fishing and natural mortality. The large fluctuations in cpue between 2008 and 2010 do not seem to be due only to the fishing effort. It is probable that the resource is also very sensitive to environmental factors so the hypothesis that the resource begins to react to climate change seems to be reasonable.

The sensitivity analysis, applied in the frame of the Schaefer model, shows that the hypothesis of the initial proportion of 0.5 resulted the most reasonable even though the coefficient of adaptability R^2 was 0.195.

It is impossible to know the true MSY if the stock is not overexploited, therefore the MSY and related parameters are as they appear now (i.e. at actual level of effort).“You cannot determine the potential yield from a fish stock without overexploiting it” (HILBORN & WALTERS, 1992).

The first scenario appears to be the most probable because the dimensions of the fishing boats do not permit them to carry more net. Activity will be theoretically increased but not during the general financial crisis because an increase in the catch does not balance the operating costs considering that if the yield increases the price paid to the fisherman it decreases immediately because the market of Selinunte is a very small local market. In any event, it is possible to increase fishing effort by a very few percentage points each year but it is mandatory to avoid the second scenario.

CONCLUSIONS

Until 2009 the stock of *Pegusa impar* in the study area was in balance despite the increase in fishing effort. A critical point seems to be specifically the year 2008. In this year the most exploited length class decreased from 160 mm to 150 mm. The most exploited size, which until 2007 was a bit larger than the size at first sexual maturity, equal to 156 mm, in 2008, became a little smaller. Therefore, in the hope that climate change, particularly influential for resources that frequent the area above the thermocline, does not contribute to the detriment of the species *Pegusa impar*, it seems necessary to avoid an increase in fishing effort in terms of capacity and/or in terms of activity and/or in terms of catchability. In the framework of a precautionary approach, it is essential to deny permissions for enlarging fishing boat dimensions and for any change to the topology or the mesh size of the trammel nets and the gill nets used. To increase the security of the fisherman at sea it is possible to change and/or increase the engine power because this does not influence fishing effort.

In any case stock conservation and management of target species of the artisanal fisheries could be regularly monitored and regulated with management measures to safeguard the resource and the habitat.

ACKNOWLEDGEMENTS

From 2002 to 2008 all data were collected in the framework of two research projects funded by the Italian Ministero delle Politiche Agricole Alimentari e Forestali and by the Italian National Research Council. The last three years of the study were funded by the National Research Council.

Many thanks to Dr. Elaine TRIGIANI for useful discussions, suggestions and for the patience demonstrated in the revision of the English version of this paper.

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Received: 18 March 2013
Accepted: 20 March 2014

Značajke životnog ciklusa i procjena stoka lista jadranskoga, *Pegusa impar* (Bennett, 1831) u plitkim priobalnim vodama jugozapadne Sicilije

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SAŽETAK

Od proljeća 2002. do zime 2011. godine provedeno je istraživanje o korištenom ribolovnom naporu u širokom zaljevu između rta San Marco i rta Granitola (jugozapadna obala Sicilije). Istraživana flota pripada priobalnom ribarstvu, u kojem su se koristile mreže plivarice i poponice, te ima sjedište u luci Marinella di Selinunte i nalazi se u sredini zaljeva. Od 2005. do 2008.g. za istraživanje životnog ciklusa korišteni su podaci sezonskih statistički značajnih uzoraka lista jadranskog *Pegusa impar* (BENNETT, 1831). Parametri rasta prema Von Bertanlaffy-jevom modelu iznosili su: L_∞ = 249 mm, k = 0.25 godina^{-1}, t_0 = - 2.0 godina za ženke; te L_∞ = 250 mm, k = 0.26 godina^{-1}, t_0 = - 1.8 godina za mužjake. Najveća procijenjena dob po očitanom otolitu je 6 + godina. Parameteri *a* i *b* dužinsko-masenog odnosa iznosili su *a* = 0.000007 and *b* = 3.0562 za ženke, te *a* = 0.000008 i *b* = 3.0157 za mužjake. Duljina pri prvom spolnom sazrijevanju iznosila je 155.82 mm kod ženiki i 156.22 mm kod mužjaka. Dob prve spolne zrelosti bila je 1.99 god. za ženke i 2.57 godina za mužjake. Mriješćenje traje tijekom proljeća i ljeta s migracijama iz većih dubina u plitke vode. Do 2007. godine duljina većine ulovljenih primjeraka je iznosila 160 mm, dok je u 2008. godini iznosila 150 mm. Godišnji ulov kolebao je između 842 kg (9743 primjerka) i 2703 kg (65345 primjeraka). Dužina položenih mreža u godišnjem ribolovnom naporu kolebala je od 3142 km do 6017 km. Procjena stoka je izrađena prema Schaeferovom modelu koristeći pri tom FMSP-CEDA softver. Najviši održivi prinos, nosivost, koeficijent lovnosti, intrinzična stopa rasta populacije i zamjenski prinos su iznosili redom 2140 kg, 7132 kg, 0,000055 kg, 1.200 kg i 1869 kg. Predviđeni trend biomase do 2020. godine pokazuje da ako se nakon 2011.g. ribolovni napor bude povećavao za 10%, iz godine u godinu, resurs će početi opadati počevši od 2013. godine.

Mada sadašnji podaci ne ukazuju da je resurs trenutno prekomjerno eksploatiran, ribolovni napor se ne bi smio povećavati.

Ključne riječi: List jadranski (*Pegusa impar*), priobalni ribolov, životni ciklus, procjena stoka, Sredozemno more