In the actual context of dramatic degradation of ecosystems and global loss of ecosystem services, ecosystem restoration emerged as a promising solution. However, there are few evidences on how restoration can improve the provision of ecosystem services and have a positive effect on human well-being. The knowledge gaps are even more dramatic for marine environments, where restoration examples and research remain underrepresented in comparison with the terrestrial realm.

The aim of this thesis is to confirm or refute if the changes in the biophysical conditions in an estuary can lead to changes in the provisioning of cultural (recreational) ecosystem services. Focusing on recreational fishing and beach recreation in the restored Nerbioi estuary (Bay of Biscay), the thesis has analysed the changes in these activities following a transdisciplinary approach: ecological (biophysical conditions), social (behaviour and perceptions of visitors) and economic (monetary valuation of non-marketed goods). The effects that future management decisions and environmental changes can cause in recreational fishing have also been explored.

This thesis highlights how investing in water sanitation of degraded estuaries can cause great achievements in the ecological integrity of the ecosystem, and also in recreational activities that are socially and economically important for visitors and local inhabitants.

azti tecnalia

eman ta zabal zazu
Universidad del País Vasco
Euskal Herriko Unibertsitatea

RECOVERY OF ECOSYSTEM SERVICES AFTER RESTORATION OF A HIGHLY POLLUTED ECOSYSTEM:
THE NERBIOI ESTUARY
Presented by Sarai Pouso Omaetxebarria
PhD Thesis 2019

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PhD Thesis

“Recovery of ecosystem services after restoration of a highly polluted ecosystem: the Nerbioi estuary”

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PhD Program

Marine Environment and Resources

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Universidad del País Vasco   Euskal Herriko Unibertsitatea

A amama

*People must feel that the natural world is
important and valuable and beautiful and wonderful
and an amazement and a pleasure*
David Attenborough

Be curious and make mistakes, be patient and don't give up
Jane Goodall

Pasioa da hemen exigitzea zilegi den gutxieneko hori
Berri Txarrak, Poligrafo bakarra

CONTENTS

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LIST OF ACRONYMS

AFI	AZTI´s Fish Index
AHV	Altos Hornos de Vizcaya
AICc	Corrected Akaike Information Criterion
CABB	Consorcio de Aguas de Bilbao-Bizkaia / Bilbao-Bizkaia Water Consortium
CBD	Convention of Biological Diversity
CES	Cultural Ecosystem Services
CICES	Common International Classification of Ecosystem Services
DAPSI(W)R(M)	Drivers, Activities, Pressures, State changes, Impact (on Welfare) and Response (Measures)
EEA	European Environmental Agency
ENPV	Economic Net Present Values
EU	European Union
EU-BS	European Union – Biodiversity Strategy
FBPC	Federación Bizkaina de Pesca y Casting
GLM	Generalized Linear Model
LRT	Likelihood Ratio Test
MEA	Millennium Ecosystem Assessment
MPN	Most Probable Number
MSFD	Marine Strategy Framework Directive
RUM	Random Utility Model
SC	Scenario
SDG	Sustainable Developing Goals
SDM	System dynamics Modelling
SDR	Social Discount Ratio
SEG	Segment
SES	Social-ecological systems
URA	Agencia Vasca del Agua / Basque Water Agency
VIF	Variance Inflation Factor
WFD	Water Framework Directive
WTP	Willingness To Pay
WWTP	Wasterwater Treatment Plant

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LABURPENA

Giza ongizatea naturaren eta ingurumen baldintzen mende dago hein batean. Ekosistema zerbitzuak gizakien ongizate hau zuzenean zein zeharka ahalbidetzen duten ezaugarri, prozesu eta funtzio ekologikoak dira. Ekosistema zerbitzuak, ordea, ez dute ibilbide zuzena egiten naturatik giza ongizatera; giza- eta gizarte-kapitalarekin erlazio eta interakzio konplexuak beharrezkoak dira ongizate hori lortzeko.

Ekosistema zerbitzuen eskaera etengabe hazten den bitartean, naturaren gehiegizko ustiapenak eta jarduera ez jasangarriek mundu-mailako bioaniztasunaren galera eta ekosistemen degradazioa eragiten dute. Egoera honek, ekosistema zerbitzuez hornitzeko naturak duen gaitasuna arriskuan jartzen du.

Itsas eta kostaldeko ekosistemen kasuan, estuarioak sistema degradatuenetarikoak dira, inguruan kontzentratzen den giza-jarduera ugariak eta giza-populazio altua direla eta. Giza-jarduera hauek, ekosistema hauen egoera ekologikoa (Europako Ur Zuzentarauaren ikuspuntutik) degradatzen duten presio eta inpaktu ugari sortzen dituzte. Ondorioz, sistema hauek ekosistema zerbitzuez hornitzeko duten gaitasuna, eta baita giza ongizatea ere, arriskuan jartzen ditu.

Giza-jardueren ondorioz degradatutako inguruetan, berreskurapen ekologikoa etorkizun handiko konponbidea da, funtzio eta prozesu ekologikoak, natura-kapitala eta ekosistema zerbitzuak berreskuratzeko. Berreskurapen ekologikoak ekosistema zerbitzuengan emaitza positiboak izan ditzakeela onartua badago ere, prozesu hau nola gertatzen den azaltzen duen ebidentzia gutxi dago.

Normalean, berreskurapen ekologiko baten emaitzen ebaluazioa baldintza biofisikoetan gertatutako aldaketetan oinarritzen da, egoera ekologiko onaren berreskurapena barne. Hau, ekosistema zerbitzuen terminologia erabiliz, ekosistema batek zerbitzuez hornitzeko duen gaitasuna aztertzearen baliokidea da. Baina, giza ongizatea lortzeko, kapital-naturala kapital ez-naturalarekin (adib. gizarte, gizaki, ekonomikoa) elkar eragin behar duela kontuan hartuta, berreskuratze baten ondorioz ekosistema zerbitzuetan eta giza ongizatean sortutako aldaketen ebaluazioa diziplinartekoa izan behar du. Hau da, ebaluazio ekologikoa, soziokulturala eta ekonomikoa konbinatu behar dira.

Berreskurapen ekologiko batek ekosistema zerbitzuetan eragin ditzakeen aldaketen azterketa lagungarria izan daiteke ekosistemen funtzionamenduaren eta ekosistema zerbitzuen artean dagoen erlazioa hobeto ulertzeko. Horrela, berreskurapen ekologikoan inbertitutako baliabideak degradatuta zeuden eremuetako biztanleriaren ongizatearen alde egin duten ebaluatzeko lagungarria izan daiteke.

Testuinguru hau kontutan hartuta, nire **hipotesia** hurrengoa da: estuario degradatu baten berreskurapen ekologikoak, eragin positiboak baldin baditu sistemaren egoera ekologikoan, emaitza positiboak izango ditu ekosistema zerbitzuen hornikuntzan ere bai. Beraz, nire **helburu nagusia,** berreskuratutako estuario baten baldintza biofisikoetan gertatutako aldaketek ekosistema zerbitzu kulturaletan (aisian) eragina izan dezaketela berrestea edo ezeztatzea da. Aldaketa hauek diziplinarteko ikuspuntu batetik aztertu dira: ekologikoa, soziala eta ekonomikoa. Helburu hori lortzeko, bi ekosistema zerbitzu kultural (kirol arrantza eta hondartzen aisi erabilera) aztertu ditut Nerbioi estuarioan (Bizkaiko Golkoa, Espainiako iparraldea). XIX. mendeko erdialdetik, Nerbioi estuarioko bi ertzetan gertatutako industrializazioak, urbanizazioak eta portu garapenak estuarioaren morfologian aldaketa sakonak eragin zituen, egoera ekologikoaren degradazioa ekarriz. Hiri eta industrietako hondakinen zuzeneko isurketak, sedimentu eta ur zutabean sustantzia kutsatzaileen akumulazioa, materia organikoan aberastea, uretako oxigeno disolbatuaren murrizketa eta komunitate biologikoen degradazio orokorra (baita zenbaiten desagertzea ere) eragin zituzten. Morfologiari dagokionez, estuarioa, ondo bereizitako bi alde dituen kanala bilakatu zen: batetik barne estuarioa, Bilboko hiria zeharkatzen duen 15km-ko ubide estratifikatua; eta bestetik kanpo estuarioa, 30 km^2 dituen kostako badia erdi-itxia.

XX. mendeko bigarren erdialdean, Espainiar iparraldeko estuario kutsatuena bihurtu zen Nerbioi estuarioa. Bertako agintariek, 1979 urtean, estuarioaren egoera estetikoa, sanitarioa eta ekologikoa berreskuratzea helburutzat zuen Saneamendu Plana onartu zuten, bertan uraren kalitatearen estandarra %60ko oxigeno saturazioan finkatuz. Nerbioi ibaiaren berreskuratze prozesua graduala izan zen eta hiru mugarri nagusi bereiz daitezke: (i) 1990ean Galindoko Hondakin Uren Araztegia (HUA) martxan jartzea tratamendu fisikoarekin; (ii) 1996an "Altos Hornos de Vizcaya" burdingintza-industria kutsakorraren itxiera; eta (iii) 2001ean, HUA-ren hobekuntza tratamendu biologikoaren gehitzearekin. Geroztik, 1989tik aurrera, estuarioaren elementu fisiko-kimiko eta biologiko desberdinen monitorizazioak egoera ekologikoaren pixkanakako hobekuntza adierazten dute. Hala ere, aldaketa hauek ekosistema zerbitzu kulturalen hornikuntzan izan duten eragina oraindik aztertu gabe zegoen.

Nire hipotesi eta helburuei erantzuteko, Tesi hau bost kapitulutan banatu dut.

A kapituluan, estuariora iristen ziren isuri kutsakorren murrizketak estuarioan dauden hiru hondartzetako bainurako uren kalitatean, eta orokorrean aisi jardueratan, eragin positiboa izan duen aztertu dut. Lehenenik eta behin, bi parametro biofisikoen (kutsadura mikrobioanoa eta ur-gardentasuna) denbora eta espazio bariazioa aztertu zen. Bigarrenik, hondartza-bisitarien jokaerak eta pertzepzioak inkesta baten bidez jaso eta ondoren aztertu egin ziren. Azkenik, parametro biofisikoak bisitarien pertzepzioekin konparatuak izan ziren. Kapitulu honen emaitzen arabera, gaur egun, estuarioak aisi jarduerak praktikatzeko baldintza hobeak eskaintzen dizkie hondartza-bisitariei (edo gaitasun handiagoa, ekosistema zerbitzuen terminotan). Estuario honetako hondartzak aisi ekintzak aurrera eramateko ingurune garrantzitsuak dira, bereziki bertako adin-ertaineko emakumeentzat. Bainurako uren hobekuntza faktore erabakigarria izan da bisitariak hondartza hauetara erakartzeko orduan, eta gehienek adierazi zutenez, hondartza hauetara ez lirateke itzuliko uraren baldintzak okerrera egingo balute. Bisitari gehienek denboran zehar gertatutako bainurako uren hobekuntzaz ohartu zirela zioten eta saneamendu planarekin erlazionatzen zuten hobetze hau. Hiru hondartzen artean zenbait ezberdintasun nabarmen aurkitu ziren. Horrela, barnealderago kokatzen den hondartzak baldintza ekologiko okerragoak ditu beste biekin konparatuz, eta egoera hau bisitarien pertzepzioekin bat dator. Azkenik, ur- gardentasunean gertatutako aldaketak eta bisitariek ur-kalitatearen aldaketen inguruan duten pertzepzioak konparatu ziren. Emaitzen arabera, faktore sozialek eragina izan dezakete bisitarien pertzepzioan. Bisitarien aisia-esperientzia (hondartza hauek bisitatzen daramatzaten urte kopurua bezala ulertua) pertzepzioen zehaztasunean eragina du, zuzenagoa izanik aisia-esperientzia luzeagoa duten bisitarien artean.

B kapituluan, hobekuntza ekologikoek kirol arrantzan eragina duten aztertu nuen. Lehenengo, ur kalitatearen eta iktiofaunaren denbora-espazio aldaketak aztertu ziren. Bigarrenez, kirol arrantzaleen jokaera eta pertzepzioak aztertu ziren inkesta baten bitartez eta kirol arrantzan jarduteko beharrezko lizentzia kopuruan gertatutako aldaketen analisiaren bidez. Azkenik, datu biofisikoak eta kirol arrantzaleek ingurumen baldintzen aldaketen inguruan dituzten pertzepzioak konparatu ziren. Ur kalitatearen (amonio kontzentrazioa eta oxigeno saturazioa) eta iktiofauna (ugaritasuna, aniztasuna eta tamaina) datuen arabera, estuarioak kirol arrantzan jarduteko dituen ingurumen baldintzak nabarmen hobetu dira berreskurapen ekologikoaren ondorioz. Beste alde batetik, kirol arrantza praktikatzeko lizentzia kopuruaren igoerak, ekintza honekiko interesa Nerbioin gora egin duela iradokitzen du. Kirol arrantzale gehienak inguruko herrietan bizi diren adin-ertaineko gizonezkoak dira, eta gehienek, lurretik arrantzatzea nahiago dute, batez ere kanpo estuarioan. Inkestako datuen arabera, arrantzaleen jokaera aldatzen joan da ingurumen baldintzak aldatzen joan ahala, eta horrela, estuarioan gero eta barrurago sartzen joan dira arrantzatzeko. Gainera, kirol arrantzaren barne estuariorako hedaketa, iraganean oso kutsatuta zeuden zonaldetara, egindako berreskurapen ekologikoaren mugarriekin bat dator. Beste alde batetik, korrelazio positiboa aurkitu zen berreskurapen abiotikoaren eta kirol arrantzaleen jokaera eta pertzepzioen artean. Ostera, aldaketa biotikoei (arrain ugaritasuna) dagokionez, kirol arrantzaleen pertzepzioak erregistratutako aldaketak baino negatiboagoak ziren. Hala ere, arrantzaleek era positiboan baloratu zuten kirol arrantzaren esperientzia estuarioan, eta gehienek, inguru honetan arrantza praktikatzen jarraitzeko intentzioa zutela aitortu zuten.

B kapituluan lortutako emaitzen arabera, kirol arrantza ekintza garrantzitsua da inguruko biztanleentzat, eta baldintza ekologikoen hobekuntzari esker, estuario osora hedatu da. Beraz, etorkizunean, baldintza ekologikoak aldatu ditzaketen kudeaketa neurriek, kirol arrantzan eragin ditzaketen inpaktuak kontutan hartu beharko dituzte. Ondorioz, C Kapituluan, etorkizuneko kudeaketa neurriek eta ustekabeko ingurugiro aldaketek (banaka eta aldaketa klimatikoaren efektuekin konbinatuta) kirol arrantzan sortu ditzaketen efektuak aztertu ziren. Gaur egungo kirol arrantza VENSIM® Sistemen Dinamika Ereduak eraikitzeko tresnarekin modelatu zen. Ondoren, etorkizuneko zazpi eszenario zehaztu eta simulatu egin ziren. Sistema sozio-ekologikoen ikuspuntua jarraituz, eredu honetan kirol arrantzaren giza dimentsioak eta dimentsio biofisikoak kontuan hartu ziren. Emaitzek adierazten dute estuarioko ingurumen baldintzak hobetzeko neurri gehiago hartuko balira, honek ondorio positiboak eragingo lituzkeela kirol arrantzan. Zehazki, uraren kalitateak hobetzen jarraituko balu, iktiofauna aldagaiek hobera egingo lukete, eta honek, kirol arrantzale gehiago erakarri ahalko lituzke haien asebetetzea igoz. Ezusteko eta behin-behineko ingurumen aldaketen simulazioek, estuarioaren baldintzen berreskurapen arina aurreikusi zuten, kirol arrantzan aldaketa lazgarririk sortu gabe. Simulazioen emaitzen arabera, berreskurapen ekologikoaren ondoren, estuarioa sistema erresilienteagoa bilakatu da, behin-behineko estresak (puntualak eta txikiak badira) jasateko gai da eta kirol arrantzan eragin latzik sortu gabe.

D eta E kapituluetan kirol arrantza eta hondartzaren aisi erabileraren balorazio ekonomikoa egin nuen, jakinarazitako lehentasunen metodoa erabiliz, zehazki, bidai gastuen modeloa. Bidai gastuen modeloak, aisi ekintzek sortutako onuren diru irabazia estimatzen du, behintzat, bisitariek aisi lekura heltzeko gastatzeko prest dauden diru kopurua bezala ulertua. D kapituluan, hondartzetako aisi erabileran zentratu nintzen, leku bakarrerako bidai gastuen modeloak eraikiz. Eraikitako ereduen arabera, uda garaiko aisi bidaien balioa 5,99 eta 8,09 € bidai^{-1} bitartekoa da. Bisitarien zenbait ezaugarri sozialek ereduak baldintzatu zituzten, efektua aldakorra izanik hondartza bakoitzean. Ikuspuntu kontserbadore bat jarraituz, hiru hondartzen aisi balio agregatua 3,5 milioi € urte^{-1}-tan estimatu zen. Onura ekonomiko hau, udako aisi bidaiekin eta estuario honek eskaintzen dituen zerbitzuetatik bakar bat aukeratuz kalkulatua izan zen. Hala ere, zerbitzu bakar honek hondartzen mantentze gastuen %100a eta saneamendu sarearen mantentze gastuen %12 kitatzeko gai da. Gastu-onura analisiaren emaitzen arabera, aurreikusitako biztanleen eta hondartzen mantentze gastuen aldaketek ez dute gastu/onura ratio positibo hau kolokan jarriko.

E kapituluan, kirol arrantzaren onuren estimazio ekonomikoa egin nuen leku anitzetarako ausazko erabilera-eredu bat eraikiz. Etorkizuneko eszenarioak zehaztuak izan ziren ingurumen baldintzak eta arrantza lekuen irisgarritasuna aldaraziz. Emaitzen arabera, ingurumen baldintzek (iktiofauna) eta irisgarritasunak (irisgarriak diren kosta-metro kopurua) kirol arrantza bidaiak baldintzatzen dituzte. Kirol arrantza bidai bakoitzaren balioa 14,98 €-tan estimatua izan zen, eta balio agregatua kirol arrantzaleen komunitate osoa kontuan hartuta 1,12 milioi € urte^{-1}-tan. Etorkizuneko eszenarioen arabera, ingurugiro baldintzak hobetzen jarraituko balute, eragin positiboa izango lukete kirol arrantzan, ekintzaren balio ekonomikoa %7,5 eta %11,5 bitartean igoaraziz. Ostera, ingurugiro baldintzen eta irisgarritasunaren okertzeak %71ko jaitsiera eragingo lukete. Estimazio hauen arabera, kirol arrantzaren gaur egungo balioak, estuarioaren ingurumen kalitatea mantentzeko beharrezkoak diren kostuen %4.7 kitatzeko gai da, betiere ingurumen kalitatea mantentzeko kostuak saneamendu sarea mantentzeko kostuak bezala estimatuz.

Laburbilduz, tesi honen emaitzen arabera, uren saneamendurako egindako inbertsioak garrantzitsuak dira kostaldeko sistema degradatuen berreskurapenerako, baldintza ekologikoetan eragiten dituzten onurengatik eta baita ere ekosistema zerbitzuen berreskurapen eta mantentzerako. Tesi honetan, bi aisi aktibitateetan gertatutako aldaketak hiru perspektiba osagarrietatik aztertuak izan dira: ingurumena, gizartea eta ekonomikoa. Diziplinarteko ikuspuntu hau hartzeak baldintza ekologiko hobeak dituzten estuarioek ekosistema zerbitzuak hornitzeko gaitasun handiagoa dutela (ingurumen perspektiba) frogatzen du; eta ekosistema zerbitzuetan gertatutako aldaketek erabiltzaileen jokaera eta pertzepzioetan (gizarte perspektiba) eta aisi ekintzen balio ekonomikoan (perspektiba ekonomikoa) eragina dutela. Gainera, tesi honek ekosistema zerbitzuen ikerketan aurrerapauso bat ematen laguntzen du, ingurumen eta gizarte perspektibak konbinatzeko gai izan baita sistemen dinamika eredu bat erabiliz eta sistema sozio-ekologikoen ikuspuntua jarraituz. Eredu honek ekosistema zerbitzuen hornikuntzan ingurumen eta gizarte faktoreen artean lotura estuak daudela frogatu du, bereziki interesgarria izan daitekeena etorkizunean hartu daitezkeen kudeaketa neurrien eraginak aurreikusteko.

Sistema berreskuratuen ekosistema zerbitzuen ebaluazioa egitea lagungarria izan daiteke ekosistemen eta giza-ongizatearen artean dauden lotura konplexuak hobeto ulertzeko. Berreskurapen proiektuen ohiko monitorizazioa, baldintza biofisikoen aldaketetan oinarritua, moldatua izan beharko litzateke zerbitzu-erabiltzaileen gizarte alderdiak gehituz. Ekosistema zerbitzuen hornikuntzarekin zerikusia duten elementu desberdinen datuak biltzean, hauen artean dauden erlazioak eta elementu baten aldaketek beste elementuetan sor ditzaken aldaketak hobeto ulertu daitezke, eta beraz, ekosistema zerbitzuen ulermenean aurrerapausoak ematen jarraitzeko lagungarria izango da.

Tesi honen emaitzek ikertzaileentzat baliagarriak izan daitezke, ingurumen berreskurapen eta ekosistema zerbitzuen hornikuntzaren artean dauden loturak hobeto ulertzen laguntzen duelako. Ulermen sakonago hau baliagarria izan daiteke bertako kudeatzaile eta aktore politikoentzat, izan ere, ingurumenaren eta gizartearen arteko loturen ulermenak ingurumen kudeaketarako erabaki informatuagoak hartzen lagundu dezakeelako.

Gaur egungo egoeran, gertatzen ari den ekosistemen degradazio latza eta ekosistema zerbitzuen galera globalarekin, tesi honen emaitzek berreskurapen ekologikorako neurriak hartzearen alde nazioartean behin eta berriro egin diren deialdiak indartzen ditu, mundu mailako joera negatibo horiei kontra egiteko berebiziko garrantzia duten ekintzak baitira. Ikerketa kasu lokal bat erabiliz, tesi honek frogatu du berreskurapen ekologikorako inbertsioak erabakigarriak izan daitezkeela ekosistemen integritate-ekologikoa lortzeko, eta baita ere, jolas aktibitateetarako; eta ekintza hauek inguruko biztanle eta bisitarientzat gizarte-onura eta onura-ekonomiko garrantzitsuak izan ditzakete. Ondorioz, hipotesia frogatua gelditu da, tesia hau izanik:

“Ingurumenaren berreskurapenak estuarioen egoera ekologikoa hobetzen laguntzen du. Honek, emaitza positiboak dauzka ekosistema zerbitzuen hornikuntzan eta gizarte-ongizatean, aisi aukerak handitzen baititu. Ekosistema zerbitzuen hornikuntzan ematen den areagotzea frogatua gelditu da: (i) ingurumenaren aldetik, hobekuntza ekologiko orokorrak ekosistema zerbitzuen hornikuntzan erabakigarriak diren faktore biofisiko zehatzen hobekuntza ekarri baitu (zerbitzuak hornitzeko gaitasuna handitu da); (ii) gizartearen aldetik, berreskurapen ekologikoaren eta honek eragin duen ingurumen kalitatearen hobekuntzaren ondorioz, erabiltzaileen jokaerak eta pertzepzioak aldatu baitira; eta (iii) ekonomikoki; ur-kalitatea mantentzeko kostuen portzentaje garrantzitsu bat kitatua gelditzen baita aisi aktibitateek duten erabilera-baloreari esker.

RESUMEN

El bienestar humano depende en parte de la naturaleza y de las condiciones ambientales, siendo los servicios ecosistémicos las características, funciones y procesos ecológicos que contribuyen, de manera directa o indirecta, a ese bienestar. Los servicios ecosistémicos no fluyen de manera directa desde la naturaleza hasta el bienestar humano, sino que son necesarias complejas combinaciones e interacciones con el capital social y humano para alcanzar dicho bienestar.

Mientras que la demanda mundial de servicios ecosistémicos continúa creciendo, la sobreexplotación de la naturaleza y las prácticas ambientales insostenibles están generando una pérdida global de biodiversidad y la degradación de los ecosistemas. Esta situación compromete la capacidad de la naturaleza de continuar proporcionando servicios ecosistémicos.

En el caso de los ecosistemas marinos y costeros, los estuarios son uno de los sistemas más degradados, debido a la alta concentración de población y de actividades humanas a su alrededor. Estas actividades generan presiones e impactos que degradan su estado ecológico (en el sentido de la Directiva Marco del Agua), lo que compromete la capacidad de estos sistemas de proporcionar servicios ecosistémicos, poniendo en peligro el bienestar humano.

En zonas degradadas por la actividad humana, la restauración ecológica es una de las soluciones más prometedoras para la recuperación del funcionamiento y de los procesos ecológicos, incluyendo el capital natural y los servicios ecosistémicos. Sin embargo, aunque está generalmente aceptado que la restauración puede tener efectos positivos sobre los servicios ecosistémicos, existen pocas evidencias de cómo sucede este proceso.

Tradicionalmente, la evaluación de los resultados tras una restauración ecológica se centra en los cambios que se originan en las condiciones biofísicas, incluyendo la recuperación de un buen estado ecológico. Esto, utilizando la terminología de los servicios ecosistémicos, equivaldría a estudiar la capacidad del ecosistema de proveer servicios. Teniendo en cuenta que, para contribuir al bienestar humano, el capital natural tiene que interactuar con otros tipos de capital no-natural (ej. social, humano,

económico), la evaluación de los cambios en los servicios ecosistémicos y en el bienestar humano tras una restauración ecológica debe ser transdisciplinar. En otras palabras, debe combinar la evaluación ecológica, sociocultural y económica.

El análisis de las consecuencias que la restauración ecológica puede tener en los servicios ecosistémicos puede ayudar a avanzar en una mejor comprensión de cómo el funcionamiento y los procesos de los ecosistemas afectan a la provisión de servicios ecosistémicos. Además, puede ayudar a evaluar si los recursos invertidos en restauración mejoran el bienestar humano de la gente que habita en los lugares previamente degradados.

Mi **hipótesis** es que la restauración de un estuario degradado, si tiene consecuencias positivas en su estado ecológico, tendrá también resultados positivos en la provisión de servicios ecosistémicos. Así pues, mi **objetivo principal** es corroborar o refutar si los cambios en las condiciones biofísicas en un estuario restaurado pueden llevar a cambios en la provisión de servicios ecosistémicos culturales (recreativos), analizando estos cambios desde una perspectiva transdisciplinar: ecológica, social y económica. Para alcanzar este objetivo, me he centrado en dos servicios culturales recreativos (pesca recreativa y uso recreativo de playas), analizándolos en el estuario del Nerbioi (Golfo de Bizkaia, norte de España). En este estuario, desde mediados del siglo XIX, la urbanización y el desarrollo industrial y portuario en ambas márgenes provocó cambios en su morfología, degradando su estado ecológico. La descarga directa de residuos urbanos e industriales causó la acumulación de contaminantes y el enriquecimiento de materia orgánica de los sedimentos y la columna de agua, la reducción de la concentración de oxígeno disuelto en agua y la degradación general (incluso desaparición) de las comunidades biológicas. En lo que respecta a la morfología, el estuario se transformó en un canal en el que hoy en día se distinguen dos zonas: la parte interna, un canal estratificado de 15 km de longitud que atraviesa la ciudad de Bilbao; y la parte externa, una bahía costera semi-cerrada de 30 km^2.

En la segunda mitad del siglo XX, el Nerbioi se convirtió en el estuario más contaminado del norte de España. En 1979, las autoridades locales aprobaron el Plan de Saneamiento con el objetivo de restaurar las condiciones estéticas, sanitarias y ecológicas del estuario, y fijando un estándar de calidad para las aguas del 60% de saturación de oxígeno. La recuperación del Nerbioi ha sido gradual y en ella se distinguen tres grandes hitos: (i) en 1990, la puesta en marcha de la EDAR de Galindo, con el tratamiento físico de las aguas residuales; (ii) en 1996, el cierre de la altamente contaminante empresa siderúrgica “Altos Hornos de Vizcaya”; y (iii) en 2001, la mejora de la EDAR con la adición del tratamiento biológico. Desde 1989, se han monitoreado diversos elementos fisicoquímicos y biológicos del estuario, mostrando una paulatina mejora del estado ecológico. Sin embargo, la influencia que estos cambios han podido tener en la provisión de los servicios ecosistémicos culturales no había sido investigada aún.

Para dar respuesta a mi hipótesis y objetivos, he dividido esta Tesis en cinco capítulos.

En el Capítulo A exploré si la reducción de las cargas contaminantes en el estuario ha contribuido a la mejora de la calidad de las aguas de baño y de la actividad recreativa en las tres playas del estuario. En primer lugar, la variación espaciotemporal de dos parámetros biofísicos (contaminación microbiana y transparencia del agua) fue analizada. En segundo lugar, los comportamientos y percepciones de los visitantes de las playas fueron recogidos a través de una encuesta y posteriormente analizados. Por último, los datos de los parámetros biofísicos fueron contrastados con las percepciones de los visitantes. Los resultados indican que, hoy en día, el estuario ofrece a los visitantes de las playas unas mejores condiciones para el recreo (o mayor capacidad, en términos de servicios ecosistémicos). Las playas del estuario son zonas importantes para el recreo, especialmente para mujeres locales de mediana edad. La mejora en la calidad del agua ha sido un factor crítico para que los visitantes decidan acudir a estas playas, y la mayoría de los visitantes indicaron que no volverían si las condiciones del agua empeoran. La mayoría de los visitantes percibieron una mejora a lo largo del tiempo de la calidad de las aguas de baño, mejora que relacionaron con el plan de saneamiento. Entre las tres playas se encontraron algunas diferencias significativas. Así, la playa más interna presenta peores condiciones ambientales que las otras dos, lo que también coincide con las percepciones reportadas por los visitantes. Por último, la comparación de los cambios en la transparencia del agua con las percepciones de cambios que tienen los visitantes de la calidad de las aguas sugiere que los factores sociales pueden influenciar estas percepciones. Así, la experiencia recreativa de los visitantes (entendida como el número de años que llevan visitando estas playas) influencia la exactitud de las percepciones, siendo ésta más ajustada a los cambios registrados en la transparencia entre aquellos visitantes con mayor experiencia recreativa.

En el Capítulo B, exploré si las mejoras ecológicas influencian la pesca recreativa. En primer lugar, se analizó la variación espaciotemporal de la calidad del agua y de las condiciones de la ictiofauna. En segundo lugar, el comportamiento y las percepciones de los pescadores recreativos fueron investigados por medio de una encuesta y recopilando los cambios en el número de licencias de pesca recreativa. Finalmente, los datos biofísicos fueron contrastados con las percepciones que los pescadores recreativos tienen de los cambios ambientales. Los datos de la calidad del agua (concentración de amonio y saturación de oxígeno) e ictiofauna (abundancia, riqueza y talla) sugieren que las condiciones ambientales para practicar la pesca recreativa han mejorado notablemente tras la restauración. Por otro lado, el incremento en el número de licencias sugiere que el interés por la actividad recreativa ha aumentado en el Nerbioi, a medida que las condiciones ambientales han mejorado. La actividad la llevan a cabo principalmente hombres locales de mediana edad que prefieren pescar desde tierra y en la parte exterior del estuario. Los resultados de la encuesta revelaron que los pescadores han ido modificando su comportamiento, de acuerdo con los cambios ambientales registrados, comenzando a pescar progresivamente en zonas cada vez más interiores del estuario. La extensión de la pesca recreativa a zonas interiores, que estaban muy contaminadas en el pasado, concuerda con los hitos de la restauración. Los resultados también mostraron una correlación positiva entre la recuperación abiótica y el comportamiento y percepciones de los pescadores recreativos. Sin embargo, las percepciones de los pescadores respecto a los cambios bióticos (abundancia de peces) fueron más negativas que los cambios registrados. A pesar de ello, los pescadores se muestran generalmente satisfechos con la experiencia de pesca en el estuario y mayoritariamente indicaron su intención de seguir pescando en la zona.

Los resultados del Capítulo B mostraron que la pesca recreativa es importante para la población local, así como que la actividad se ha extendido a todo el estuario tras las mejoras ambientales registradas. Por lo tanto, las futuras medidas de gestión que pudieran cambiar el estado ecológico del estuario deben considerar su impacto en la pesca recreativa. Así pues, en el Capítulo C, me he centrado en la pesca recreativa con el objetivo de analizar los efectos que las futuras medidas de gestión y cambios ambientales inesperados, tanto aisladamente como en interacción con los efectos del cambio climático, pueden ocasionar en la pesca recreativa. La actividad recreativa actual se modeló utilizando VENSIM®, una herramienta de Modelado de Dinámica de Sistemas. Posteriormente, se definieron y simularon siete escenarios de futuro. Siguiendo el enfoque de sistemas socio-ecológicos, en el modelo se incluyeron las dimensiones biofísica y humana de la pesca recreativa. Los resultados sugieren que la adopción de medidas para la mejora de las condiciones ambientales puede conllevar cambios positivos en la pesca recreativa. En concreto, si la calidad del agua continúa mejorando, también mejorarán las variables de ictiofauna, lo que puede atraer a más pescadores y aumentar su satisfacción. La simulación de cambios ambientales imprevistos y temporales resultaron en una recuperación rápida del estuario y sin condiciones dramáticas para la actividad recreativa. Los resultados de las simulaciones sugieren que, tras la restauración, el estuario es un sistema más resiliente, capaz de absorber un estrés eventual que se produzca (si es puntual y no intenso), y sin efectos considerables para la pesca recreativa.

En los Capítulos D y E llevé a cabo la valoración monetaria de las dos actividades recreativas, utilizando para ello métodos de preferencias reveladas, en concreto, el método de coste de viaje. El método de coste de viaje estima el valor monetario de los beneficios recreativos como, al menos, lo que los visitantes están dispuestos a pagar para llegar al sitio de recreo. En el Capítulo D, me centré en el uso recreativo de las playas, construyendo modelos de coste de viaje para lugar único. Los modelos revelaron que los viajes recreativos en época estival tienen un valor de 5,99-8,09 € viaje^{-1}. Hubo diversas características sociales de los visitantes que influenciaron estos modelos, siendo su efecto variable entre playas. Adoptando un enfoque conservador, el valor recreativo agregado de las tres playas se estimó en más de 3,5 millones € año^{-1}. Este beneficio económico, calculado únicamente con los viajes de verano de uno de los múltiples servicios que ofrece este estuario, es suficiente para cubrir el 100% de los costes de mantenimiento de las playas y el 12% del coste de mantenimiento de la red de saneamiento. Los resultados del análisis coste-beneficio mostraron que futuros cambios en la población y en los costes de mantenimiento de playas previsiblemente no comprometerán el signo positivo del ratio coste/beneficio.

En el Capítulo E, me centré en la pesca recreativa, valorando los beneficios de la actividad, utilizando modelos aleatorios de utilidad para múltiples lugares. Los escenarios de futuro utilizados para analizar los efectos en los beneficios recreativos fueron definidos en base a cambios en las condiciones ambientales y en la accesibilidad de las zonas de pesca. Los resultados indicaron que las condiciones ambientales (ictiofauna) y la accesibilidad (metros de costa accesibles) afectan a los viajes de pesca recreativa. Cada viaje de pesca recreativo fue valorado en 14,98 €, con un valor agregado de 1,12 millones € año^{-1} para toda la comunidad de pescadores recreativos del Nerbioi. Los escenarios simulados sugieren que las mejoras ambientales tendrán un efecto positivo en la actividad, lo que podría incrementar el valor económico entre 7,5-11,5%. Por el contrario, el empeoramiento de las condiciones ambientales y la accesibilidad podría traducirse en una reducción de los beneficios de hasta un 71%. Según estas estimaciones, el valor actual de la pesca recreativa cubre parcialmente (4,7%) los costes de mantenimiento de la calidad ambiental del estuario, calculados como el coste de mantenimiento de la red de saneamiento.

Resumiendo, los resultados de esta tesis resaltan que las acciones de saneamiento de las aguas son importantes para la recuperación de sistemas costeros degradados, en términos de mejora de las condiciones ecológicas, y también para la recuperación y/o mantenimiento de sus servicios ecosistémicos. En esta tesis, los cambios acaecidos en las dos actividades recreativas han sido estudiados desde una triple perspectiva complementaria: ambiental, social y económica. La adopción de este enfoque transdisciplinar demuestra que los estuarios en mejores condiciones ecológicas tienen la capacidad de proveer más servicios ecosistémicos (perspectiva ambiental); y que los cambios en los servicios ecosistémicos se ven reflejados en cambios en el comportamiento y percepciones de los usuarios (perspectiva social) y en la valoración económica de las actividades recreativas (perspectiva económica). Además, esta tesis contribuye a avanzar en la investigación de los servicios ecosistémicos, al ser capaz de combinar las perspectivas ambientales y sociales en un modelo de dinámica de sistemas, desde una perspectiva socio-ecológica. Este modelo demuestra los fuertes vínculos que existen entre factores ambientales y sociales en lo que respecta a la provisión de servicios ecosistémicos, lo que puede ser especialmente útil para anticipar las consecuencias de medidas de gestión futuras.

La evaluación de servicios ecosistémicos en sistemas restaurados puede ayudar a avanzar en la mejor comprensión de las relaciones complejas que existen entre los ecosistemas y el bienestar humano. El monitoreo tradicional de los proyectos de restauración, centrado en los cambios en las condiciones biofísicas, debería ser adaptado e incorporar aspectos sociales relacionados con los usuarios de los servicios. La recopilación de datos de los diferentes elementos involucrados en la provisión de servicios ecosistémicos ayudará a comprender mejor las relaciones que existen entre estos elementos y cómo reaccionan ante los cambios, lo que permitirá avanzar así hacia una mejor comprensión de los servicios ecosistémicos.

Los resultados de esta tesis pueden ayudar a los investigadores a comprender mejor los vínculos entre la recuperación ambiental y la provisión de servicios ecosistémicos. Esta mejor comprensión puede ser valiosa para los gestores locales y actores políticos, ya que una mejor comprensión de las relaciones naturaleza-ser humano permitirá tomar decisiones mejor informadas en gestión ambiental.

En el contexto actual de la dramática degradación de los ecosistemas y la pérdida global de servicios ecosistémicos, los resultados de esta tesis respaldan los numerosos llamamientos internacionales en favor de la adopción de medidas de restauración ecológica, como acciones vitales para invertir estas tendencias globales negativas. Esta tesis ha probado, utilizando un caso de estudio local, cómo las inversiones en restauración pueden conseguir grandes logros en materia de la integridad ecológica de los ecosistemas, y también en forma de actividades recreativas que tienen un beneficio social y económico importante para los habitantes del entorno y los visitantes. En conclusión, he corroborado la hipótesis planteada, siendo la tesis:

“La restauración ambiental en estuarios contribuye a mejorar su estado ecológico, lo que tiene efectos positivos en la provisión de servicios ecosistémicos y en el bienestar humano, a través del incremento de oportunidades de recreo. El efecto positivo de la restauración en la provisión de servicios ecosistémicos ha sido probado: (i) ambientalmente, ya que la mejora ecológica generalizada ha conllevado la mejora de factores biofísicos específicos que son cruciales para el recreo; (ii) socialmente, con los cambios en el comportamiento y percepciones respecto a la mejora de la calidad ambiental; y (iii) económicamente, ya que un porcentaje importante de los costes de mantenimiento de la calidad del agua se cubren con el valor de uso de las actividades recreativas."

SUMMARY

Human well-being depends on nature and environmental conditions; being ecosystem services the ecological characteristics, functions or processes that directly or indirectly contribute to it. Ecosystem services do not flow directly from nature to human well-being; on the contrary, complex combinations and interactions with human, social and built capital are needed to produce human benefits.

While the demand for ecosystem services continues to increase, overexploitation of nature and unsustainable environmental practices are generating the loss of biodiversity and degradation of ecosystems, compromising the capacity of the nature to provide ecosystem services.

Among marine and coastal ecosystems, estuaries are some of the most degraded ones, due to the high concentration of human population and activities around them. Human activities in estuaries generate intense pressures and impacts that degrade their ecological status (as defined in the Water Framework Directive) and jeopardizes their capacity to deliver ecosystem services, consequently, threatening human well-being.

In human-degraded ecosystems, ecosystem restoration emerged as the most promising solution to recover ecological functions and processes, including natural capital and ecosystem services. It is generally accepted that restoration can have positive outcomes in provision of ecosystem services; however, there are still few evidences on how this process occurs.

Traditionally, the evaluation of ecological restoration outcomes has focused on the changes in biophysical conditions, including the recovery of the good ecological status. Using the terminology of ecosystem services research, this will be equal to study the capacity of the ecosystem to provide services. In order to contribute to human well-being, the natural capital needs to interact with other non-natural capital (i.e. social, human and built capital). Therefore, the valuation of changes in ecosystem services and human well-being after restoration must be transdisciplinary. In other words, it must combine ecological, socio-cultural and economic valuation.

Assessing the consequences of restoration in ecosystem services can help to advance towards a better comprehension on how ecosystems´ functioning and

processes affect the provisioning of ecosystem services. Also, it can help to evaluate if the investments made in the restoration project influence human well-being living in previously degraded sites.

The **hypothesis** is that an environmental restoration process in an estuarine system, which had positive effects in the ecological status, will also have positive effects in the provision of ecosystem services. The **aim** is to confirm or refute if the changes in the biophysical conditions of a restored estuary can lead to changes in the provisioning of cultural (recreational) ecosystem services, analysing these changes from a transdisciplinary perspective: ecological, social and economic. For achieving this aim, I focus in two cultural services (recreational fishing and beach recreation) and analyse them in the case study of the Nerbioi estuary (Bay of Biscay, North of Spain). From the mid-19th Century, the intense the urbanization, industrial and port developments happening in the Nerbioi estuary area changed its morphology and degraded its environmental health status. The discharges of untreated urban and industrial wastes caused the accumulation of pollutants and the organic enrichment of the sediments and the water column, the reduction of the concentration of dissolved oxygen in the waters and the general degradation (even absence) of the biological communities. Morphologically, the estuary was transformed nearly into a tidal channel with a good differentiation of two zones: the inner part, a highly stratified channel of 15 km length that crosses the city of Bilbao; and the outer part, a semi-enclosed coastal embayment of 30 km^2.

In the second half of the 20th Century, the estuary became the most polluted estuary in northern Spain. In 1979, the Sanitation Scheme was approved by the local authorities, with the aim to restore the aesthetics, sanitary and ecological conditions of the estuary, and to achieve a water quality standard of 60% oxygen saturation. The Nerbioi´s recovery has been gradual, after the following three main milestones: (i) in 1990, the beginning of the Wastewater Treatment Plant (WWTP) of Galindo with physical and chemical treatments; (ii) in 1996, the closure of the highly polluting iron and steel industry “Altos Hornos de Vizcaya” (AHV); and (iii) in 2001, the addition of the biological treatment in the WWTP. Since 1989, the physical-chemical and biological elements of the estuary have been monitored, showing a clear ecological improvement, but the concurrent response of cultural ecosystem services remains unexplored.

In order to answer to the hypothesis and aim, the thesis has been divided in five chapters.

In Chapter A, I explored if the reduction of pollution loads improved the quality of bathing waters and consequently, recreational ecosystem services in the three estuarine beaches. Firstly, the temporal and spatial variation of two biophysical parameters was analysed (i.e. microbial pollution and water transparency). Secondly, beach visitors´ behaviour and perceptions were captured through a questionnaire and analysed. Finally, biophysical data were compared with visitors´ perceptions. After the results, nowadays the estuary offers beach visitors with better conditions (i.e. higher ecosystem service capacity) to recreate. Estuarine beaches are important recreational areas, mainly for local middle-age women. The water quality improvement was found to be a critical factor for deciding to visit these beaches and most visitors answered that they would not return if water conditions deteriorate. Most visitors perceived an improvement in bathing waters quality and linked it to the estuarine sanitation. Significant differences existed between beaches, with the most inner beach presenting worse environmental conditions than the other two beaches; and matching user´s perceptions. Finally, the comparison of registered changes on water transparency with visitors´ perceptions on changes on water quality suggest that social factors can influence those perceptions. Thus, experience (i.e. number of years visiting Nerbioi beaches) influences the perception accuracy, being more accurate among visitors with longer recreational experience.

In Chapter B, I explored if ecological improvements influenced recreational fishing. Firstly, the temporal and spatial variation of water quality and fish conditions were analysed. Secondly, data on recreational fishers´ behaviour and perceptions were captured through a questionnaire and data on the number of recreational fishing licenses. Finally, biophysical data were crossed with visitors´ perceptions on environmental changes. Data on water quality (i.e. ammonium concentration and oxygen saturation) and fish parameters (i.e. fish abundance, richness and size) suggest that biophysical conditions for practicing recreational fishing improved after restoration.

The increase in the number of licences suggest a growing interest for recreational fishing in Nerbioi, as environmental conditions improved. The activity is performed mainly by local middle-age men who prefer to fish from shore and preferably in the outer Nerbioi. Fishers changed their behaviour in response to environmental changes, as the progressively entered to the inner estuary. The progressive extension of recreational fishing to inner areas that were severely polluted in the past, matches the recovery milestones. Results also show a positive correlation between the abiotic ecological recovery and fishers' behaviour and perceptions. However, fishers´ perceptions on the biotic recovery (e.g. fish abundance) were more negative than those recorded. Despite this, fishers are satisfied with the overall experience of fishing and will probably continue fishing in the estuary.

The findings in Chapter B showed that recreational fishing is important for the local population and that the activity has extended to the whole estuary, after environmental amelioration. Therefore, future management measures that could cause changes in the estuary ecological status should also consider their impact on recreational fishing. In Chapter C, I focused in recreational fishing with the objective of analyzing the effects that future management decisions and unexpected environmental changes, alone or in combination with climate change effects, can produce in recreational fishing. The current recreational fishing activity was modelled using VENSIM®, a System Dynamics Modelling (SDM) tool. Then seven future environmental management scenarios were defined and simulated. Following a social-ecological system approach, the model included variables from both biophysical and human dimension of the recreational activity. Results suggested that the adoption of future management measures to improve the environmental conditions could lead to additional positive changes for recreational fishing. Precisely, if water quality continues to improve, fish stocks will continue to recover, and these better conditions could attract more fishers and increase their satisfaction. Simulation of temporary and unexpected environmental changes resulted in quick estuarine recovery, without dramatic consequences for recreational fishing. Simulation results suggest that after restoration, Nerbioi is a more resilient system, able to absorb the stress (if punctual and non-intense) and without severe effects for recreational fishing.

In Chapter D and E, I performed monetary valuations of the two recreational activities using revealed preference approaches, specifically travel cost methods. Travel cost methods estimates the monetary value of recreational benefits to be at least what visitors are willing to pay to get to the recreation site. In Chapter D, I focused in beach recreation, building single-site travel cost models for the three beaches and performing a partial cost-benefit analysis. The travel cost models reveal that summer recreational trips to Nerbioi beaches have a value of 5.99-8.09 € trip^{-1}. Visitor's profile and social characteristics influenced the models, while the effects of these variables also varied across beaches. Following a conservative approach, the aggregate recreational value of the estuarine beaches was estimated to be more than 3.5 million € year^{-1}. This economic benefit, obtained from summer estimates and focusing on a single recreational activity (i.e. beach recreation) from the multiple ones offered by the estuary, is enough to cover 100% of annual beach maintenance costs and 12% of the annual sewerage system running costs. After the cost-benefit analysis results, expected changes in population and beach maintenance costs would not compromise the positive sign of the cost/benefit rate.

In Chapter E, I focused in recreational fishing, valuing the benefits of this activity through a multi-site random utility model (RUM). Future scenarios were defined based on environmental conditions and accessibility changes, to analyse the effect on welfare measures. Results indicate that environmental variables (i.e. fish conditions) and accessibility (i.e. metres of accessible shoreline) conditioned the recreational trips. Each recreational trip in Nerbioi has a use value of 14.98 €, with an aggregate value of 1.12 million € year^{-1} for the whole recreational fishers´ community. The simulated scenarios suggest that further environmental improvements would have a positive effect in the activity, increasing the current welfare by 7.5-11.5%. Opposite, worsening of environmental conditions and accessibility could translate into a welfare reduction up to 71%. Accordig to these estimates, the monetary use value of recreational fishing partially covers (4.7%) the costs of maintaining the environmental quality of the estuary (i.e. sewerage system running costs).

All in all, the findings of this thesis highlight that water sanitation actions are important for the recovery of degraded coastal environments (in terms of ecological conditions) and for the recovery and/or maintenance of ecosystem services. In this thesis, changes in two recreational activities were analysed from a triple and complementary perspective: environmental, social and economic. The adoption of this transdisciplinary approach demonstrated how better functioning estuaries have the capacity to deliver more ecosystem service (i.e. environmental perspective); and changes in ecosystem services can be reflected in users´ behaviour and perceptions (i.e. social perspective) and in the monetary valuation of the recreational activities (i.e. economic perspective). Furthermore, this thesis took a step forward and combined the environmental and social perspectives into a dynamics model, following a social-ecological approach. This model demonstrated the strong links and interrelation between environmental and social factors in ecosystem services provisioning, which could be especially useful to envisage the effects of future scenarios.

Performing ecosystem services assessment in restored ecosystems helps to advance the understanding of the complex links between ecosystems and human well-being. The traditional perspective of monitoring restoration projects that focuses on changes in biophysical conditions, should be adapted to incorporate social aspects related with service users. Collecting data on the different elements involved in the ecosystem services provisioning will help to understand how those elements are interlinked and how they react to changes, advancing towards a better comprehension of ecosystem services.

The findings of this thesis can help researchers to better comprehend the links between environmental recovery and the provision of ecosystem services. A better comprehension of these links can be valuable information for local managers and policy-makers, as more accurate comprehension of the nature-human relations could assist them to make informed decisions in environmental management.

In the actual context of dramatic degradation rates of ecosystems and global loss of ecosystem services, the findings of the current thesis support the numerous international pledges that have been done to restore damaged ecosystems, and the arguments towards the vital role that restoration actions play in reversing these global trends. This thesis proved, using a local case study how investing in restoration can cause great achievements not only for the ecological integrity of the ecosystem, but also in the form of recreational activities that have a social and economic revenue for local inhabitants and visitors. Consequently, the thesis is that:

"The environmental restoration of estuarine systems contributes to the improvement of their ecological status having positive effects in the provision of ecosystem services and in human well-being, by means of an increase of recreational opportunities. The positive effects of restoration in the provision of ecosystem services have been proved: (i) environmentally, as the overall ecological improvement lead to the amelioration of specific biophysical factors crucial for recreation; (ii) socially, by changes in recreationalists´ behaviour and perceptions over environmental quality improvement; and (ii) economically, since an important percentage of the costs to maintain the water quality is covered by the use-value of recreational activities."

GENERAL INTRODUCTION

1. Introduction

Human well-being denotes a physical, social and mental state that is intrinsically valuable to human beings (Alexandrova, 2012). Human well-being has four major components: basic human needs, economic needs, environmental needs, and subjective happiness (Summers *et al.*, 2012). The fundamental link between humans and nature is clearly inherent to the human well-being concept, as all the human well-being components are directly or indirectly influenced by environmental dimensions (Summers *et al.*, 2012; Jax and Heink, 2016).

Ecosystem services are the ecological characteristics, functions or processes that directly or indirectly contribute to human well-being (Costanza *et al.*, 1997; Millennium Ecosystem Assessment, 2005a). When referring to the ecosystems that provide such services, the term **natural capital** is frequently used (Costanza *et al.*, 2017). Although sometimes natural capital and ecosystem services are used indistinctively, they are well-differentiated concepts: natural capital refers to the world´s stocks of natural assets, including geology, soil, air, water and all living organisms (World Forum on Natural Capital, 2018), while ecosystem services are the flows yielded from the stock (i.e. natural capital) that, in combination and interacting with other types of capital, contribute to human well-being (Costanza and Daly, 1992; Costanza *et al.*, 2014, 2017). In short, natural capital is independent to human activity, while ecosystem services require human activity to build or maintain human benefits.

From the multiple, but yet similar, **ecosystem services classification systems** that have appeared over the last decades (Costanza *et al.*, 2017), the Common International Classification of Ecosystem Services (CICES) distinguishes between three types of ecosystem services: (i) provisioning services, which are described as all nutritional, non-nutritional material and energetic outputs from living systems and abiotic outputs (e.g. fish as food intake); (ii) regulation and maintenance services, which cover all the ways in which living organisms can mediate or moderate the environment that affects human health, safety or comfort, together with abiotic equivalents (e.g. storm protection by coastal wetlands); and (iii) cultural services, which refer to the non-material outputs of ecosystems that affect physical and mental states of people (e.g. practicing recreational activities in natural settings) (Haines-Young and Potschin, 2013, 2018).

There is a general consensus on the idea that human well-being depends on ecosystem services (Millennium Ecosystem Assessment, 2005a). However, as mentioned before, ecosystem services do not flow directly from natural capital to human well-being; complex combinations and interactions of natural capital (in the form of ecosystem services) with human, social and built capital are needed to produce human benefits (Costanza *et al.*, 2014) (Figure 1). Human capital refers to the people, social capital to communities, and built capital to the built environment (e.g. facilities, infrastructures, etc.) (Costanza *et al.*, 2014). Human, social and built capital can also be referred to as **non-natural capital** (Outeiro *et al.*, 2017).

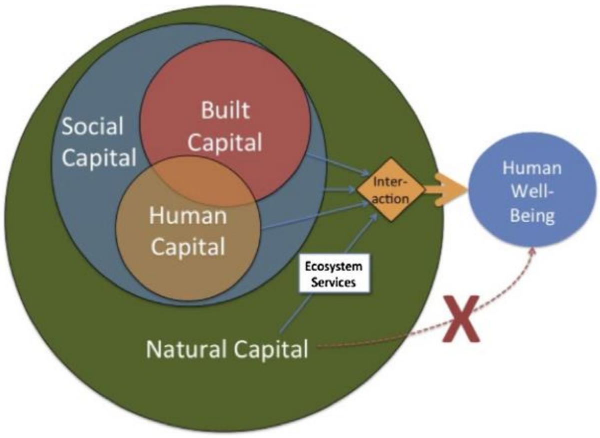


Figure 1 *- The different types of capital and interactions involved in the production of human well-being. Built and human capital are embedded in society which is embedded in the rest of nature. Source: Costanza et al. (2014).*

In ecosystem services research, the idea that an interaction between natural and non-natural capital is mandatory to contribute to human well-being, matches the claim in favour of adoption of the **social-ecological system approach** (Outeiro *et al.*, 2017). The adoption of this systemic approach means admitting that all the resources used by humans are embedded in complex systems, composed of four first-level subsystems (i.e. resource system, resource units, users and governance systems) that interact to produce outcomes affecting the different elements of the system, as well as linked social, economic and political settings and related ecosystems (Ostrom, 2009) (Figure 2). Using the social-ecological approach for ecosystem services valuation and assessment is considered a powerful tool that can help to better understand and analyze how nature and society interact with each other to produce outcomes in the form of human well-being (Ostrom, 2007, 2009; Reyers *et al.*, 2013; Costanza *et al.*, 2017).

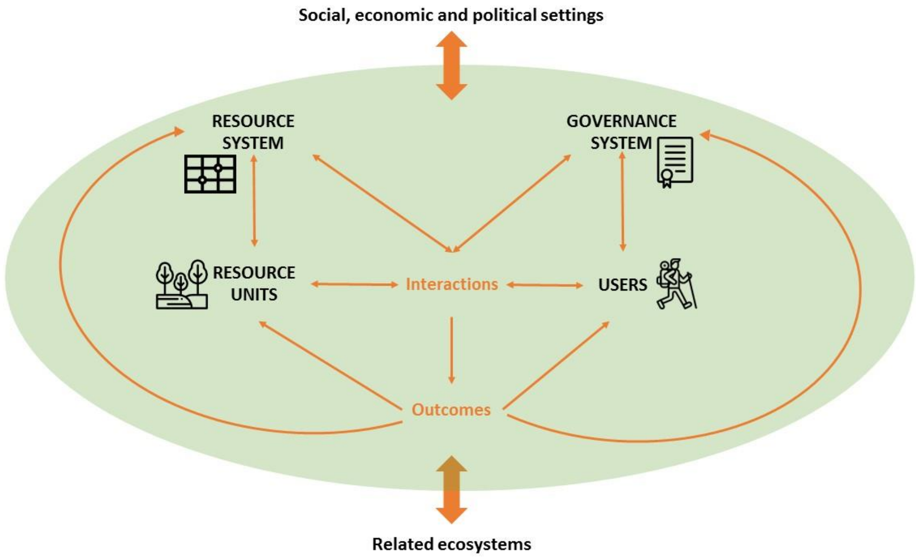


Figure 2 - *First-level subsystems for analysing social-ecological systems. Adapted from Ostrom (2009).*

The social-ecological system approach goes in line with the shift in conservation thinking, from the idea of "nature for people" to **"people and nature"** (Mace, 2014). This new conservation framework implies recognizing that the nature-people relationship is a two-way relationship, where nature affects people and *vice versa* (Carpenter *et al.*, 2009). It could be applied to different spatial scales and it incorporates concepts and knowledge from different disciplines such as resource economics, sociology and theoretical ecology (Carpenter *et al.*, 2009; Ostrom, 2009; Mace, 2014). In opposition to the "nature for people" thinking, where the relation between them was seen as linear and unidirectional, the "people and nature" thinking and the social-ecological system approach explicitly recognize the important role played by social, institutional and economic factors and their interactions with nature, in the production of human well-being (Millennium Ecosystem Assessment, 2003; Mace, 2014; Costanza *et al.*, 2017).

Considering the ideas behind "nature and people" and the social-ecological system approach, the assessment and valuation of ecosystem services should be addressed adopting a **transdisciplinary science approach** (Carpenter *et al.*, 2009; Costanza *et al.*, 2017). The multiple and diverse elements involved, as well as the complex relationships between them, require professionals from different backgrounds to work together to integrate the knowledge gained in the social, economic and ecological aspects of ecosystem services´ understanding, modelling, measuring and managing, consistently with the nature of the problems being analysed (Liu *et al.*, 2010; Costanza *et al.*, 2017).

The transdisciplinary science approach is suited for carrying out the **integrated valuation of ecosystem services,** which is preferred over single-valuation approaches (Jacobs *et al.*, 2016). Valuation of ecosystem services is "the process of assessing the contribution of ecosystem services to meeting a particular goal or goals" (Liu *et al.*, 2010). Ecosystem services have three valuation domains: ecological, economic and socio-cultural values (De Groot *et al.*, 2002). Traditionally, valuation followed a single-value approach and therefore, provided a partial and incomplete value of the ecosystem services and natural capital. Most frequently, ecosystem service valuation has solely focused on economic and ecological valuation approaches, which with their inherent limitations have constrained a correct and complete valuation of the extent of ecosystem services contribution to human well-being. On the one hand, **ecological valuation**, which attends exclusively to biophysical measures of the system (i.e. natural capital), neglects people´s perceptions and preferences (Spangenberg and Settele, 2010). On the other hand, traditional **economic valuation** approaches (e.g. revealed and stated preference techniques) derive values based on individual human perceptions for the many ecosystem services that lack a formal market (Turner *et al.*, 2010; Costanza *et al.*, 2017), ignoring the rest of elements in which human well-being depends: the sustainable use of natural capital and the social welfare (Bockstael *et al.*, 2000; Costanza *et al.*, 2017). Furthermore, the use of economic valuation approaches in ecosystem service research has been considered a risk as it could facilitate the process of commodification of ecosystem services (Gómez-Baggethun and Ruiz-Pérez, 2011). The **socio-cultural** is the third domain in ecosystem services valuation (De Groot *et al.*, 2002), which refers to the ecosystem services contributions that define, support, and enhance the culture of a society (Braat *et al.*, 2015) but has been less studied (Costanza *et al.*, 2017).

The confirmation of the ineffectiveness of traditional single-value approaches to capture the complexity of the social-ecological systems that provide ecosystem services and human well-being, has boosted the research on **integrated valuation approaches**. This approach contemplates the multidimensional identity of ecosystem services (Martín-López *et al.*, 2014) and advocates for a valuation perspective that combines the value from the ecosystem services valuation domains (i.e. ecological, socio-cultural and economic) (Gómez-Baggethun *et al.*, 2014) to support decision-making processes (Jacobs *et al.*, 2016). Adopting an integrated approach for ecosystem service valuation will provide a more complete valuation of ecosystem services and therefore, contribute to secure the sustainability of complex social-ecological systems in the long term.

All the theoretical concepts for ecosystem services´ assessment and valuation explained in the previous paragraphs should be translated into practice by transforming them into **environmental policies**; this would enable to progress towards sustainable management schemes where decisions are taken considering the important role played by ecosystem services for human well-being (Turner and Daily, 2008; Martino *et al.*, 2019). New environmental policies should be designed in such manner that they ensure the sustainable management of the natural capital (i.e. water, air, soil, etc.) with complete integration of the role of the non-natural elements involved in the provision of ecosystem services and human well-being (Reyers *et al.*, 2013; Turner *et al.*, 2016).

However, the current consideration of ecosystem services in policies and management decisions is scarce, in part due to the important **knowledge gaps** around the concept. The most remarkable knowledge gaps are related with the little comprehension on the interactions between natural capital and non-natural capital needed to provide ecosystem services and to contribute to human well-being (Carpenter *et al.*, 2009; Costanza *et al.*, 2017). Consequently, the knowledge that society has on the critical role of ecosystem services for human well-being remains scarce, leaving (i) ecosystem services without clear protection measures, and (ii) their true value out of economic decision-making processes (Millennium Ecosystem Assessment, 2005a; Carpenter *et al.*, 2009; Liu *et al.*, 2010; Chan *et al.*, 2017).

Nowadays, overexploitation of natural capital and unsustainable environmental practices are generating the loss of biodiversity and **degradation of natural resources and ecosystems,** which ultimately compromises the capacity of the natural systems to provide ecosystem services (Carpenter *et al.*, 2006; Díaz *et al.*, 2006; Carpenter *et al.*, 2009; Outeiro *et al.*, 2017). At the same time, the demand for ecosystem services continues to increase (Liu *et al.*, 2010).

In order to reverse the degradation of ecosystems, several **international and national agreements and policies** have been approved. In the last decades, the focus of environmental policies has been placed in securing the well-being of future generations. For achieving it, it is considered necessary to promote the sustainable use of nature and halt the global loss of biodiversity and of ecosystem services, by reducing the pressures on nature and restoring degraded ecosystems.

The **Sustainable Developing Goals** (SDG) presented by the United Nations (2016), represent the most recent global effort done to influence policies and incorporate environmental objectives to management measures. The main objective of the SDG is to address the global challenges faced by human beings, such as poverty, inequity, climate, environmental degradation, prosperity, and peace and justice.

At some extent, some of these SDGs (i.e. in the marine realm, SDG14 on "Conserve and sustainably use the oceans, seas and marine resources for sustainable development") are rooted in the first and most remarkable global effort done to halt the global loss of biodiversity, which is the **Convention on Biological Diversity** (United Nations, 1992), implemented through the strategic plan 2011-2020 and the Aichi Targets. The main objective of the CBD is "the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" (United Nations, 1992). Through its strategic plan, the signing countries aim for halting loss of biodiversity in order to secure that ecosystems are resilient and able to provide services that contribute to human well-being by 2020. Some of the actions mentioned in the plan are: to reduce pressures on biodiversity, to restore ecosystems, to implement appropriate policies and to base decision-making on sound science and the precautionary approach.

In Europe, the ratification of the CDB together with the confirmation that the biodiversity policy was not achieving its targets, lead to the adoption of the **EU Biodiversity Strategy** (EU-BS) in 2011. The main objective of the EU-BS is "to halt the loss of biodiversity and improve the state of Europe´s species, habitats, ecosystems and the services they provide" (European Commission, 2011). The strategy aims at reducing key pressures on nature and ecosystem services in the EU. Considering the vague incorporation of ecosystem services into environmental policies, EU-BS is the first attempt for European legislation highlighting the important contribution that ecosystem services make to human well-being.

In the aquatic realm, there are two specific European directives that focus on the protection of aquatic biodiversity and environments: the **Water Framework Directive** (WFD; 2000/60/EC) and the **Marine Strategy Framework Directive** (MSFD; 2008/56/EC) (Borja *et al.*, 2010b). The objective of the WFD is to achieve good ecological status for all water bodies by 2015 (now, 2021) and avoid their deterioration, supporting the adoption of protection and restoration measures. In turn, the main objective of the MSFD is to establish a framework to achieve or maintain good environmental status in the marine environment by 2020. Despite the policy development in Europe, the directives have not been able to either halt or reverse the declining trends in biodiversity of aquatic ecosystems (EEA, 2015), and the integration of the ecosystem services approach on policies for aquatic environments is still scarce (Rouillard *et al.*, 2018). Therefore, these ecosystems still follow a degrading trend and compromises their capacity to provide ecosystem services and contribute to human well-being. This is generally true for estuaries, which have historically supported a high concentration of human population (O'Higgins *et al.*, 2010) and multiple human activities, being the producer and supplier of many ecosystem services (Barbier *et al.*, 2011).

Indeed, **estuaries** are some of the most damaged and degraded aquatic ecosystems worldwide (Lotze *et al.*, 2006). These diverse but also fragile ecosystems have supported a high concentration of human activities around them, which generated numerous pressures and impacts, degrading their ecological status and jeopardizing their capacity to deliver ecosystem services (Lotze *et al.*, 2006; Barbier *et al.*, 2012; Barbier, 2017). Therefore, as it happens in other ecosystem types, society and individuals are necessary, in the form of non-natural capital, for securing the provision of estuarine ecosystem services and human well-being; but at the same time, they can generate pressures that translate into undesirable changes in ecosystem status, consequently impacting welfare and becoming an important threat for human well-being.

Ecosystem restoration emerged as the most promising solution to recover natural assets and ecosystem services in human-degraded ecosystems (Benayas *et al.*, 2009), including estuaries (Elliott *et al.*, 2007). Restoration encompasses "all the activities which seek to upgrade and improve the damaged area, recreate what had been destroyed, recover its use and restore its biological potential" (Bradshaw, 2002). There is general agreement on the ability of ecological restoration to improve biodiversity, contribute to achieving the good ecological status, and to increase the provision of ecosystem services (Bullock *et al.*, 2011; Everard, 2012). In environmental management, the aforementioned policies (i.e. CBD, EU-BS, WFD and MSFD) included ecosystem restoration as a necessary action to halt biodiversity loss; some of them (EU-BS, MSFD) also mentioned it as necessary for securing ecosystem services.

Ecological restoration is seem not only as a way to halt the degradation of ecosystems but also as a means of improving human well-being (Matzek *et al.*, 2019). Indeed, evaluation of changes in the biophysical conditions and on ecosystem services after the implementation of restoration measures is considered a crucial step to **evaluate the success** of the investments made (Carpenter *et al.*, 2009; De Groot *et al.*, 2013). In this context, ecosystem services valuation can be used as measurement of restoration success (Bullock *et al.*, 2011; Borja *et al.*, 2015). If the assessment of ecosystem services on a restored system focuses on the nonmarket ecosystem services, such as **cultural ecosystem services**, the process will have certain peculiarities: while the ecological (i.e. biophysical) valuation will assess the capacity of the restored ecosystem to provide ecosystem services, the socio-cultural valuation will study the contribution of nature to human well-being by analysing human preferences. These preferences could change as a response to restoration measures that modify the ecological status and may, therefore, create new opportunities to enjoy the system (e.g. increase in recreational opportunities). The socio-cultural valuation would need focusing on the change in social perceptions and behaviour towards those new or recovered ecosystem services. In this context, the incorporation of social aspects is crucial, as social differences among users bring different conclusions (Kumar and Kumar, 2008). Finally, the economic valuation will focus on placing a monetary value to those social preferences, using nonmarket valuation techniques. The monetary value of ecosystem services can be compared with the investments and costs of restoration measures by performing a cost-benefit analysis (Spurgeon, 1998). Despite the clear utility of these valuations, when using the changes in marine and coastal ecosystem services as a measure of ecological restoration success, some of the limitations around the concepts of ecosystem services and restoration should be considered.

Firstly, the restoration pathway in an ecosystem will usually be different to the degradation pathway, meaning that the recovered stable state achieved after restoration will be different to the previous undisturbed stable state. The difference between those two stable states is known as **hysteresis** (Elliott *et al.*, 2007). Also, in a reality of **shifting baselines** due to large-scale environmental changes, returning ecosystems to a particular past state is unlikely; therefore, the definition of precise states to be achieved after restoration should be replaced by the more realistic objective of arriving to alternative stable states that are able to supply valuable ecosystem services (Duarte *et al.*, 2009, 2015).

The second limitation is related with the **lack of knowledge** on how ecosystem functioning and processes affect the provisioning of ecosystem services (Carpenter *et al.*, 2009). Little effort has been done in research to better understand the interactions between the different types of capital (i.e. natural, built, human and social capital) and to which extent each type contributes to human well-being (Liu *et al.*, 2010; Costanza *et al.*, 2017; Martino *et al.*, 2019). These knowledge gaps complicate the demonstration that changes in biophysical conditions after restoration are the real cause behind changes in ecosystem services, and ultimately, in human well-being. This lack of knowledge is even more dramatic in marine systems, where restoration examples and research on ecosystem services remain underrepresented in comparison with those in the terrestrial realm (Liquete *et al.*, 2013; Borja *et al.*, 2015).

The third limitation is connected with ecosystem services valuation, which is a complex process still lacking of a clear definition on what and how needs to be measured (Boyd *et al.*, 2016). Ecosystem services valuation is considered a necessary process to secure the sustainable management of ecosystems and to translate ecosystem services into terms that decision-makers and the public can understand (Carpenter 2006). However, despite the general consensus on the idea that valuation should be done adopting an integrated valuation approach (Gómez-Baggethun *et al.*, 2014), debate on how to do it is still an important research issue (De Groot *et al.*, 2010), especially in marine ecosystems (Martino *et al.*, 2019).

The consequence of these limitations is that nowadays, there are **few evidences on how restoration actions in degraded marine and coastal systems can improve ecosystem services**. The few available examples suggest positive outcomes; even if the valuation was done adopting an economic single-value perspective and, therefore, provided an incomplete picture and a likely underestimation of the effects on human well-being (Spurgeon, 1998; De Groot *et al.*, 2013; Edwards *et al.*, 2013).

Therefore, advancing in knowledge on the links between restoration, ecosystem services and human well-being is a current research hot topic in marine environments, which is required to better inform policy-making and therefore, secure the sustainability of future environmental management decisions.

In marine environmental management, the **nested-DAPSI(W)R(M) framework** presented by Elliott *et al.* (2017) is a problem structuring framework that could be a useful tool to explain the degradation and posterior restoration pathways from an ecosystem services approach. Any research and management project carried out in the complex marine environment needs to consider all the users and uses involved, and therefore, needs to follow a holistic approach where all the natural and social aspects are included. The nested-DAPSI(W)R(M) is an integrated approach that links all the aspects involved in the supply of benefits to society (i.e. contribution to human well-being) (Elliott *et al.*, 2017). In short, the framework considers that basic human needs (Drivers - D) are achieved through human activities (A). These human interventions create changes (Pressures - P) that lead to environmental alterations in the system (State changes -S). Changes can have an impact on the environmental and societal welfare (I(W)). In this thesis, I-Impact and W-Welfare have been differentiated by considering as I the impacts on the environment (such as biodiversity) and as W the impacts on human welfare (such as the specific benefits obtained through ecosystem services). In order to address the pressures, state changes and impacts created from a certain human activity, society needs to adopt management measures (Response using Measures – R(M)). Successful measures would prevent state changes and impacts on welfare and could also have a positive effect on other marine-based activities. DAPSI(W)R(M) could represent a certain activity, but as marine activities are interconnected (e.g. the pressure generated by one activity could negatively affect other activity); the relations between the different activities can be represented by nesting several DAPSI(W)R(M) frameworks between them (Atkins *et al.*, 2011; Elliott *et al.*, 2017) (Figure 3).

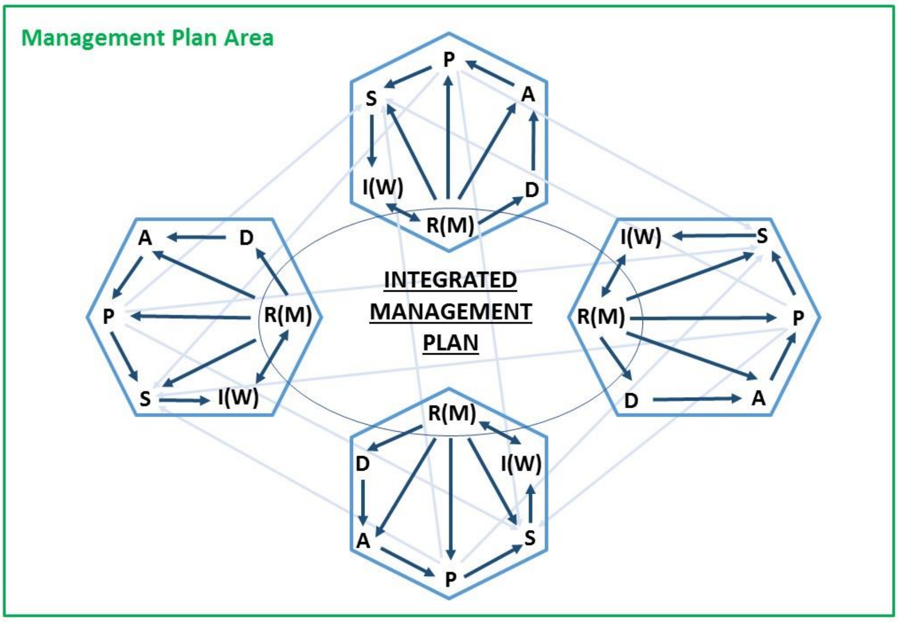


Figure 3 - *Example of a nested-DAPSI(W)R(M) framework of a hypothetical marine area. Key: D – Drivers; A – Activities; P – Pressures; S – State changes; I(W) – Impacts (on Welfare); R(M) – Responses (as Measures). Adapted from Elliott et al. (2017).*

Using the DAPSI(W)R(M) framework, it is possible to explain how in a degraded marine ecosystem, where restoration measures were adopted to remove a pressure, the state changes after pressure removal created the appropriate conditions for the emergence of new human activities that contribute to human well-being. In other words, better environmental conditions after ecosystem restoration not only could remove pressures and improve the quality of the environment, but also create the adequate conditions for new human activities that increase human well-being. These new activities, at the same time, could create their own pressures, state changes and impact on welfare, and therefore they will need their own response measures. The nested-DAPSI(W)R(M) framework is a useful tool for marine environmental management, as it helps to get a complete picture of all the activities (and their interactions) happening in marine ecosystems.

All in all, any future **valuation of ecosystem services in restored marine systems** should be carried out clearly relating the ecosystem services to its social benefits (Olander *et al.*, 2018). The analysis should be done considering the direction of the ecosystem services theoretical framework (integrated valuation, transdisciplinary approach, social-ecological systems, etc.) and should not forget about the limitations inherent to ecological restoration and ecosystem services assessment and valuation. Also, the use of nested-DAPSI(W)R(M) framework could help to better understand the relations between the different human activities happening in the (degraded and later restored) ecosystem.

2. Hypothesis, aim and objectives

2.1. Hypothesis

After the context previously presented, the hypothesis is that an environmental restoration process in an estuarine system, which had positive effects in physical-chemical and biological components (i.e. in the ecological status), will also have positive effects in the provision of ecosystem services.

2.2. Aim and objectives

Taken the above-mentioned hypothesis into account, the aim of this thesis is to confirm or refute if the changes in the biophysical conditions of a restored estuary can lead to changes in the provisioning of cultural (recreational) ecosystem services, analysing these changes from a transdisciplinary perspective: ecological, social and economic.

For achieving the aim, I focus in two recreational activities (recreational fishing and beach recreation) and analyse them in the case study of the Nerbioi estuary (Bay of Biscay, North of Spain). The aim was divided into four objectives:

1. To evaluate the changes in the natural capital (physical-chemical and biological parameters) recorded in time series that potentially can have an effect in beach recreation (Chapter A) and recreational fishing (Chapter B).
2. To evaluate to which extent the changes in natural capital induced changes in social behaviour and perceptions towards beach users (Chapter A) and recreational fishers (Chapter B), captured through questionnaires.
3. To build a system dynamic model that helps to analyse the provision of the cultural service “recreational fishing” and forecast the effects that different scenarios can cause in the ecosystem services and the recreational activity (Chapter C).
4. To perform economic valuations of the two mentioned recreational activities, after the implementation of the restoration measures, using monetary valuation techniques for nonmarket ecosystem services, such as single-site travel cost for beach recreation (Chapter D) and a random utility model for recreational fishing (Chapter E).

In the general discussion, the results of the partial analyses have been combined in order to perform an integrated valuation of beach recreation and recreational fishing recovery after the restoration.

3. Case study

The Nerbioi estuary[1], located in the inner Bay of Biscay (43°23´- 43°14´N, 3°07´- 2°55´W) on the coast of the Basque Country (Spain) (Figure 4), is a mesotidal estuary (2.5 m mean tidal variation, between +1.2 and +3.7 m) (Leorri *et al.*, 2008) with a mean river flow of 25 $m^3 s^{-1}$ (García-Barcina *et al.*, 2006). The freshwater inflow in the estuary comes mainly

[1] In the scientific literature it appears named under the synonymous names of Bilbao estuary (García-Barcina *et al.*, 2006; Cajaraville *et al.*, 2016), Nervión estuary (Leorri *et al.*, 2008; Irabien *et al.*, 2018) and Nervión-Ibaizabal estuary.

from the Nerbioi-Ibaizabal rivers system (66%) and Kadagua river (27%), while the remaining 9% comes from the Asua, Gobelas and Galindo rivers (García-Barcina *et al.*, 2006; Uriarte *et al.*, 2014). The contribution of the freshwater inflow to the total water volume is low in comparison with the tidal water, being most of the estuary usually euhaline (salinity > 30) (Cajaraville *et al.*, 2016).

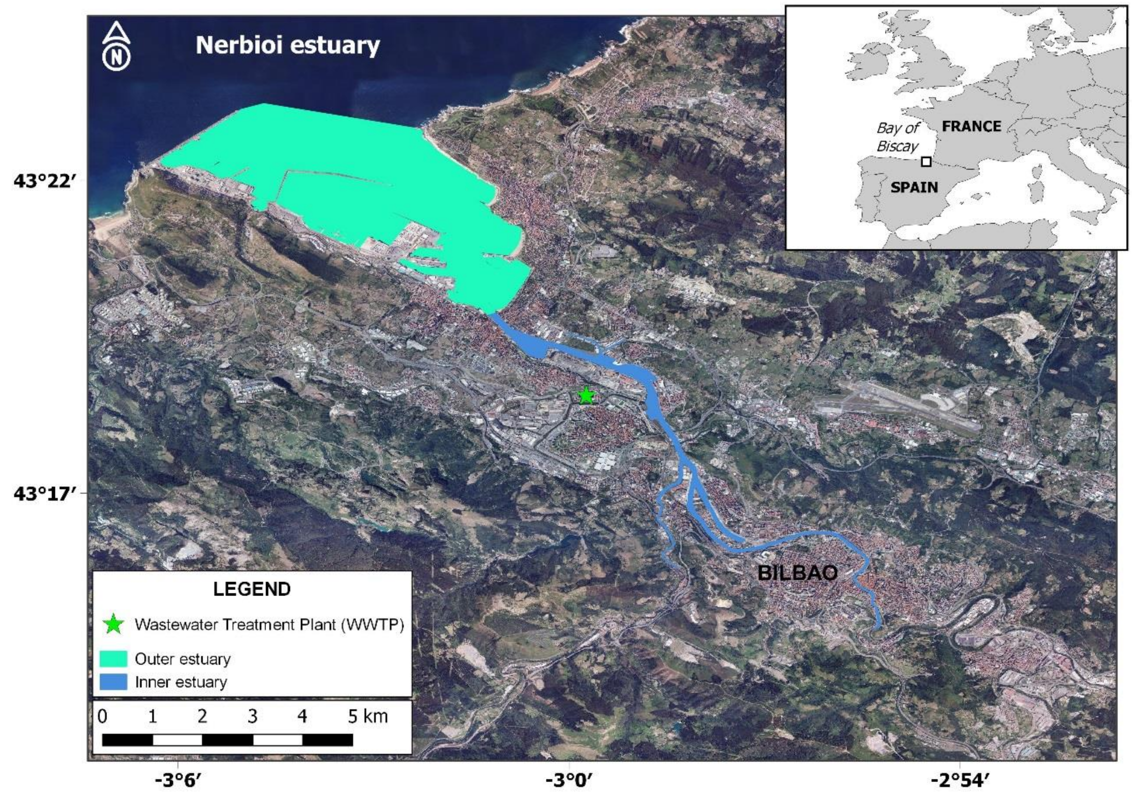


***Figure 4** – Location of the Nerbioi estuary within the Bay of Biscay and location of the Wastewater Treatment Plant of Galindo (WWTP).*

From the mid-19th Century, the urbanization, industrial (i.e. mining, steel and chemical industries) and port developments caused a deep change in the estuarine morphology. Nowadays, the two banks of the estuary are completely occupied by human activities. The nine villages located on the estuarine banks have a total population of 694,139 inhabitants (Eustat, 2017), which constitutes 32% of the total population of the Basque Country and is the highest concentration of inhabitants of the region.

The intense human activities changed the estuarine morphology and caused an estuarine-area loss of more than 1,000 Ha (Rivas, 1991). The Nerbioi was transformed nearly into a tidal channel (Cearreta *et al.*, 2004), with a good differentiation of two zones: the inner part, a highly stratified channel of 15 km length, 25-270 m width and 2-9 m mean depth that crosses the city of Bilbao; and the outer part, also known as the "Abra", a semi-enclosed coastal embayment of 30 km^2, 3.5 km mean width and an average depth of 25 m (Leorri *et al.*, 2008; Irabien *et al.*, 2018).

For more than 150 years, the multiple human activities happening in the estuarine area not only transformed the morphology of the estuary but also degraded its environmental health status. Indeed, in the second half of the 20th Century, the Nerbioi estuary became the most polluted estuary in northern Spain (Cearreta *et al.*, 2000). The continuous discharges of untreated urban and industrial wastes caused the accumulation of pollutants and the organic enrichment of the sediments and the water column, the reduction of the concentration of dissolved oxygen in the waters (with episodes of hypoxic and anoxic conditions in the inner estuary) and the general degradation (even absence) of the biological communities (Belzunce *et al.*, 2001, 2004a; Gorostiaga *et al.*, 2004; Borja *et al.*, 2006).

In 1979, the Sanitation Scheme was approved by the local authorities, with the aim to restore the aesthetics, sanitary and ecological conditions of the estuary, and to achieve a water quality standard of 60% oxygen saturation (Pascual *et al.*, 2012). The Nerbioi´s recovery has been gradual, after the following three main milestones (Borja *et al.*, 2010a): (i) in 1990, the beginning of the Waste Water Treatment Plant (WWTP) of Galindo with physical and chemical treatments; (ii) in 1996, the closure of the highly polluting iron and steel industry "Altos Hornos de Vizcaya" (AHV); and (iii) in 2001, the addition of the biological treatment in the WWTP.

The closure of industries, the WWTP implementation and the limitations imposed by more restrictive environmental policy caused a decline of metals, organic compounds and faecal pollution inputs into the estuary, reducing the pollutant concentrations in estuarine waters and sediments (Belzunce *et al.*, 2004a, 2004b; García-Barcina *et al.*, 2006; Borja *et al.*, 2016b; Irabien *et al.*, 2018), and consequently recovering, among others, benthic communities (Borja *et al.*, 2006) and demersal fishes (Uriarte and Borja, 2009); as reflected in the increase of the general biological value within the estuary (Pascual *et al.*, 2012).

The physical-chemical and biological elements of the estuary have been monitored and studied since 1989 and the results have been communicated in many scientific publications and policy reports. This information is used in this thesis to explore the consequences of the environmental (biophysical) restoration in the recovery of ecosystem services and human well-being (Figure 5).

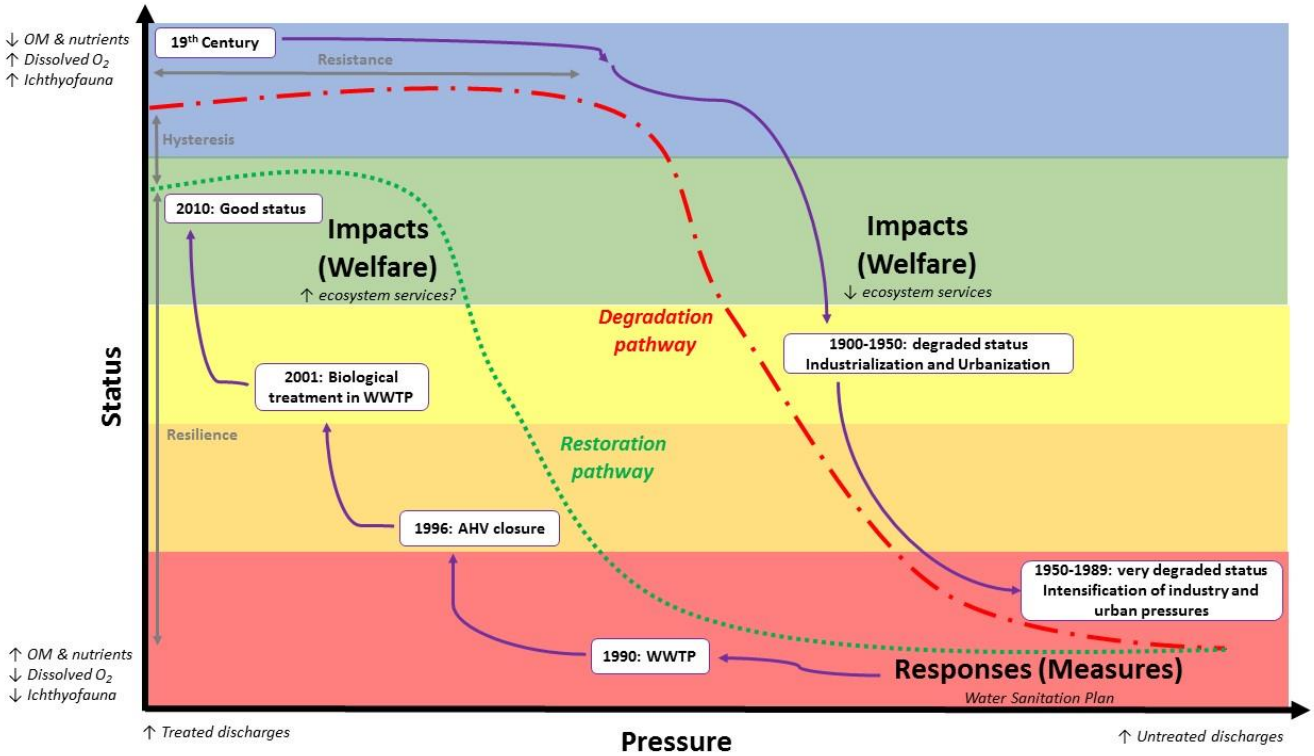
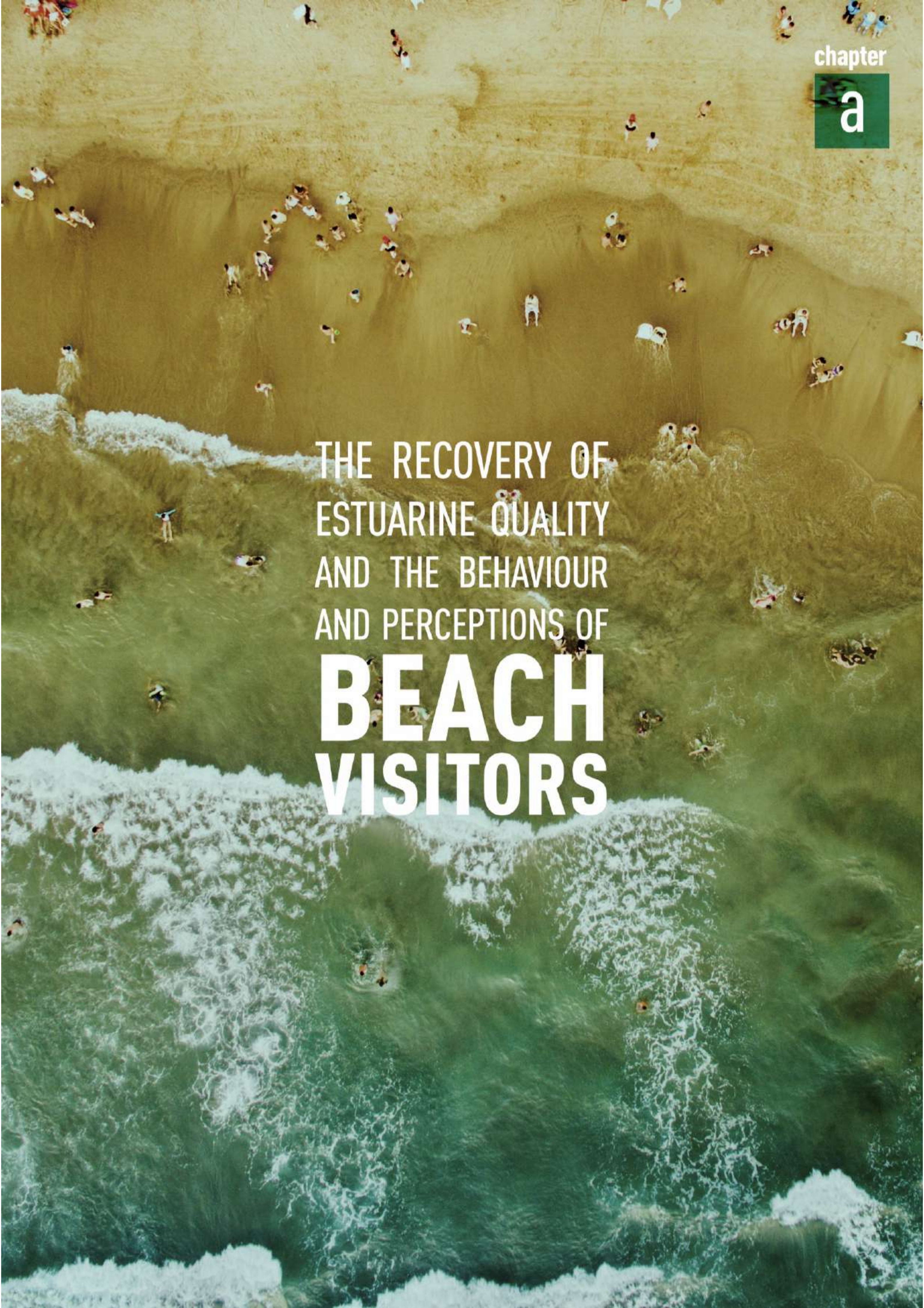


Figure 5 – *Degradation and restoration pathways in the Nerbioi estuary, as a Status vs. Pressure graph. Background colours represent the degradation status of the estuary (red=very degraded, orange=degraded, yellow=moderately degraded, green=good status, blue=very good status). Key: WWTP= Waste Water Treatment Plant; OM=Organic matter; R(M)= response as measures; I(W)=impacts on welfare. Purple arrows indicate the main phases of the degradation and restoration processes in the Nerbioi estuary.*



chapter a

THE RECOVERY OF ESTUARINE QUALITY AND THE BEHAVIOUR AND PERCEPTIONS OF BEACH VISITORS

Abstract

In Europe, the quality of coastal bathing waters improved considerably in the last decades, mainly due to the more demanding legislation and the adoption of water sanitation plans. In the Nerbioi estuary (North Spain), the WWTP implemented between 1990 and 2001 resulted on an abrupt decrease in microbial concentration; thus, complying with bathing waters legislation and allowing recreational activities again in the three beaches of the estuary. However, little is known about how improvements in bathing waters influences the provision of cultural ecosystem services and human well-being. A questionnaire was used to study beach users´ behavior and perceptions and compared with environmental time-series data (microbial concentration and water transparency). Most respondents perceived an improvement in bathing waters quality and linked it to the estuarine sanitation. Nerbioi beaches are important recreational areas, mainly for local visitors, and water quality improvement was found to be a critical factor for deciding to visit these beaches. Furthermore, most visitors answered that they would not return if water conditions deteriorate. Significant differences existed between beaches, with the most inner beach presenting worse environmental conditions than the other two beaches; and matching user´s perceptions. These findings highlight that water sanitation actions are important for the recovery of degraded coastal environments and for the maintenance of ecosystem services. Also, that multidisciplinary research is necessary to better comprehend the links between environmental recovery and the provision of ecosystem services.

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1. Introduction

Estuarine and coastal areas attract diverse anthropogenic activities (Barbier *et al.*, 2011) and concentrate a high proportion of human population worldwide. Indeed, 40% of the global population lives within 100 km from the coast, with 71% of them living no further than 50 km from an estuary (Agardy and Alder, 2005), concentrating a large and diverse number of human activities. These activities (e.g. urban, industrial and touristic activities) entail numerous pressures and impacts to these environments, causing rapid degradation of their ecological status (Jackson, 2001; Davenport and Davenport, 2006; Lotze *et al.*, 2006) and jeopardizing their capacity to deliver ecosystem services (Millennium Ecosystem Assessment, 2005b; Barbier, 2017). Among the multiple ecosystem services that estuarine and coastal environments provide, cultural ecosystem services are defined as those that provide recreational, aesthetic spiritual and educational benefits to society (Hernández-Morcillo *et al.*, 2013).

Recreational activities and tourism are some of the most important human activities developed in coastal environments, in terms of economic resources mobilization and the high number of people that attract (Gormsen, 1997; Hall, 2001). Some of the most intense coastal recreational sites are beaches (Schlacher *et al.*, 2014), composed by the sandy shore and the adjacent water body (i.e. bathing waters), which are also some of the most impacted and degraded coastal areas due to the intense anthropogenic pressures they support (Defeo *et al.*, 2009). One of the most negative human impacts affecting beach recreation is the microbial water pollution arriving from diffuse and point sources, that degrades bathing waters (Quilliam *et al.*, 2015) and entails a health risk for users (Prüss, 1998; Abdelzaher *et al.*, 2011).

The negative consequences that bathing waters degradation could cause in local economies and human well-being (Given *et al.*, 2006; Ofiara and Seneca, 2006) have raised both scientific and policy interest. So far, the most common responses to revert beach degradation are ecological restoration and the establishment of more restrictive water quality legislation (e.g., (US Government, 2000; European Commission, 2006; Health Canada, 2012). Many countries have legislation and guidelines to manage the health risks associated to recreational waters such as USA (US Government, 2000), Australia (Australian Government, National Health and Medical Research Council, 2008), and Canada (Health Canada, 2012). Particularly, in the European Union, a robust legislation has been established to promote a sustainable development of human maritime activities, to halt degradation of coastal environments and to protect them (e.g. European Commission (2006, 2008). Bathing waters have been regulated by different Directives since 1975 (European Commission, 1976, 2006). These Directives established the microbiological concentration limits for protecting human health and are mandatory for monitoring bathing water within Europe. The approval of gradually more demanding legislation on water quality standards is having a positive effect in the recovery of beach quality in Europe (European Environmental Agency, 2017).

Indeed, perceptions of beach users are known to be affected, among other parameters, by bathing water quality (Tudor and Williams, 2003; Ofiara and Seneca, 2006). Some studies found that clean water is one of the most important parameters when choosing a beach (Roca and Villares, 2008). Although water quality in beaches is assessed by microbial concentration limits, beach users value different variables to judge water cleanliness, such as clarity (Peng and Oleson, 2017). Users perceptions on beach quality are important to understand the service flow between natural systems and cultural ecosystem services. For this reason, determining to which extent the improvement of a beach element (i.e. bathing waters) influences the overall satisfaction of beach visitors, and ultimately their well-being, is an important issue in environmental management. Indeed, the flow between natural systems and human benefits is not straightforward (Mace *et al.*, 2012; Reyers *et al.*, 2013); it partially depends on how humans value nature. However, people value nature in a multidimensional way (Chan *et al.*, 2012; Cundill *et al.*, 2017), which in turn affects the perception of the benefits they obtain from nature. Being the delivery of cultural services strongly linked to social factors (Reyers *et al.*, 2013), the perceptions of people benefiting from those services should be taken into account when defining indicators for cultural services (Kumar and Kumar, 2008; Hernández-Morcillo *et al.*, 2013).

This investigation focuses on the case of the three beaches inside the Nerbioi estuary, which were severely degraded by industrial and urban wastewaters during the 19th and 20th centuries but have progressively recovered over the last 25 years. The objective of this study is to establish if the environmental recovery of the natural system and the estuarine water sanitation meant an improvement in the delivery of cultural ecosystem services and human well-being, stated as the perceptions and behaviour of beach visitors, with a special focus on bathing waters. The study has three operational goals: (i) to assess the change on bathing waters status, through environmental data; (ii) to analyse if perceptions and behaviour of beach users have changed over time after the environmental changes registered in beaches; and (iii) to check if there is a correspondence between beach users´ perceptions and environmental data.

2. Methods

2.1. Study area

The three studied beaches (Areeta, Ereaga and Arrigunaga) are located in the estuary of Nerbioi (Figure A1). From the three beaches, Ereaga, the middle one, has the largest sandy-shore area (882 m length x 64 m width), followed by the outermost beach, Arrigunaga (628 m x 68 m). The beach with the smallest sandy-shore is Areeta (240 m x 25 m), which is located closer to the inner part of the estuary. Bathing waters at the three beaches correspond with the adjacent 200 meters-width water body, as stated in the corresponding legislation (Spanish Government, 2014). Nowadays, the bathing waters of these three beaches are the only bathing water areas declared inside the estuary.

During the second half of the 20th Century, the estuary was severely degraded (Borja and Collins, 2004), affecting its three internal beaches (García-Barcina *et al.*, 2002) and limiting their recreational use. In 1979, a water sanitation plan was approved by local authorities (Pascual *et al.*, 2012) with the aim of restoring the good aesthetic, sanitary and ecological conditions in the estuary and the recovery of the estuarine beaches. The sanitation plan and the implementation of posterior management measures allowed the progressive recovery of the Nerbioi waters (Cajaraville *et al.*, 2016) and the estuarine ecological quality (Borja *et al.*, 2016b). The resulting reduction in the faecal pollution allowed the gradual recovery of the bathing waters in the beaches, achieving this way the requirements set by the European legislation (García-Barcina *et al.*, 2006). In Ereaga and Arrigunaga, the quality of bathing waters reached

European and national standards in 2002 (Health Department of the Basque Country, personal communication), while at the innermost beach (Areeta) those were met in 2009, when bathing was allowed again (AZTI, 2011).

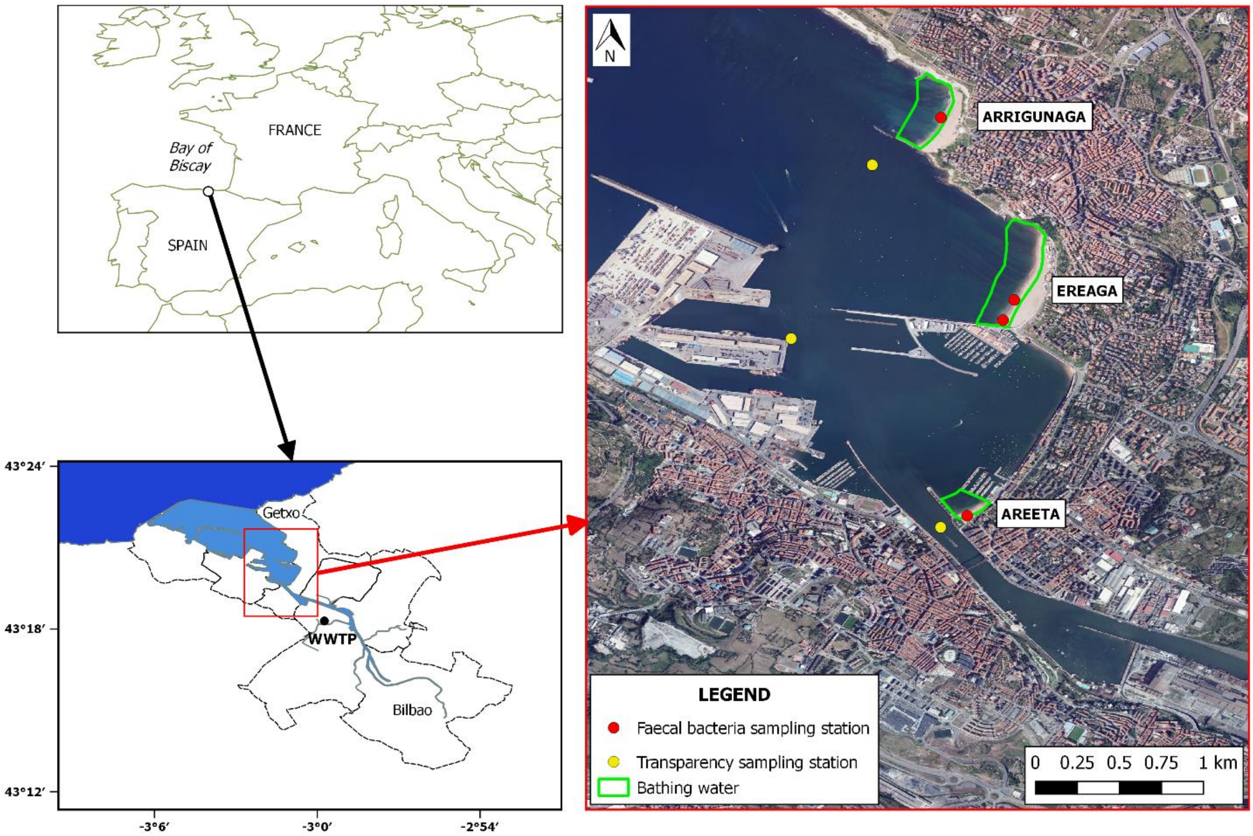


Figure A1 - *Location of Nerbioi estuary within the Bay of Biscay, showing the position of the Waste Water Treatment Plant (WWTP) of Galindo, the three beaches investigated and the sampling stations for environmental variables.*

2.2. Bathing water quality data

For understanding whether the progressive estuarine recovery had a positive effect on bathing waters in Nerbioi beaches, the sources of information used were: (i) Secchi disk depth as mean of water transparency for the period 1999-2016, collected by the Bilbao-Bizkaia Water Consortium (CABB) monitoring programme; and (ii) data from microbiological monitoring of the three beaches, carried out by the Basque Government during summer season for the period 1985-2016. The measurements of these two variables are not undertaken simultaneously, as they are carried out by different institutions, at different sampling points and with a different sampling frequency. From now onwards, all these data sets are referred as “environmental data”.

Water transparency was measured at three sampling stations, located offshore at a variable distance from the beaches (Figure A1). At each station and from the shady side of the boat, a Secchi disk (30 cm diameter) was lowered down beyond a point of disappearance, then raised and lowered slightly to set the Secchi depth. The minimum detectable depth was considered at 0.2 meters. From 1999 to 2016, between 5 and 11 data observations were recorded at each sampling station every year.

The monitoring of microbial pollution in bathing waters is carried out at the sampling stations indicated in Figure A1 (i.e. one in Areeta and Arrigunaga, and two in Ereaga). Water samples are collected during summer, from late May - early June (i.e. some days before the beginning of the bathing season) till the end of September - early October (i.e. the end of the bathing season), fortnightly or weekly, in the established sampling points inside the bathing water area. After the European and Spanish legislation for bathing water, during the period 1985 – 2007, the monitored parameters were total coliforms, faecal coliforms and faecal streptococcus (European Commission, 1976; Spanish Government, 1988; Ibarluzea *et al.*, 2000). From 2008 onwards, and in accordance with the new water quality standards (European Commission, 2006; Spanish Government, 2007), previous microbial parameters were replaced by *Escherichia coli* (*E. coli*) and intestinal enterococci.

Since the targeted monitoring microbial indicators changed after 2006, to analyse temporal trends in microbial pollution in the three beaches throughout the studied period, faecal coliforms data (Ereaga: 1985-2007; Arrigunaga: 1992-2007) and *E. coli* data (all beaches: 2008-2016) were used. In Areeta, microbial concentration has been monitored only after 2008, since previously the quality of the area was too bad to declare waters at this beach as with bathing potential (AZTI, 2011). There is some discussion on the comparability of these two microbial indicators (Kinzelman *et al.*, 2003; Jin *et al.*, 2004), as the values of *E. coli* tend to be higher (Aragonés *et al.*, 2016); however, as those were the data available, they were used to show the response of the system to sanitation throughout the studied period.

Information about how samples were collected and the quantification methods can be found in the corresponding legislation and the following additional references

(European Commission, 1976; Spanish Government, 1988; Ibarluzea *et al.*, 2000; Bald *et al.*, 2004; European Commission, 2006; Spanish Government, 2007). In total, between 11 and 21 samples of each microbial parameter were available for each sampling station and year.

2.3. Characterization of beach users and perceptions

A questionnaire was designed and distributed with the aim of characterizing Nerbioi beach visitors, capturing beach users´ behaviours and perceptions regarding the water quality at the three beaches of study and assessing cultural services. The questionnaire was translated into the two official languages of the region, Spanish and Basque, and comprised a total of 35 qualitative and quantitative questions of different kind structured into five sections (see the complete survey translated to English at Appendix A1).

The questions that the survey wanted to elucidate were: (i) what is the socio-economic profile of beach users?; (ii) what are their motivations and reasons to visit these beaches? (iii) what are their perception of the current situation of the beaches and their bathing waters?; (iv) did users perceive any change in the estuarine environmental conditions that affected or benefited their recreational activity?; and (v) what are the main differences between the three beaches, in terms of visitor´s profile and perceptions? Questions (i) and (ii) were answered through questions related to socio-economic characteristics of the respondents, general interest and motivation for going to the beach and practicing aquatic activities. Question (iii) was answered by a set of questions where respondents described the main characteristics of their visit to Nerbioi beaches and assessed the status of different characteristics of these beaches. Experienced visitors (those who began to visit these beaches before 2010), answered additional questions to capture perceptions on changes in beaches and ecosystem services, as well as how likely was that they would stop visiting Nerbioi beaches if certain characteristics were to worsen again. Analysis of those responses allowed to answer question (iv). Finally, question (v) was answered by the comparison of surveys completed at the different beaches.

To develop a scientifically robust design and comprehensive content, the questionnaire was tested in January 2016 with 12 researchers and technicians from AZTI institute, and in July 2016 with 20 users of Ereaga beach. After adaptation of the questionnaire, and during summer 2016, the questionnaire was distributed by a single interviewer in the three beaches. The interviews were carried out by the author at the beaches during July and August (high season), from Monday to Saturday, between 10:00 and 19:00 and mainly in sunny days to increase sampling success. The interviewer also recorded the date, time and number of survey trials, number of rejections and number of completed questionnaires in each sampling event. The interviewer selected potential respondents in an aleatory way, and only people older than 16 years old were asked to complete the questionnaire.

To obtain a balanced and representative sample of participants, the interviewer distributed questionnaires according to beach visitation rates in the three previous bathing seasons (from June to September 2013-2015). This information was derived from Bizkaia Regional Government data (personal communication).

2.4. Statistical analysis

Microbiological variables were analyzed through the 90th (P90) and 95th (P95) concentration percentiles (equations 1 and 2), measured as MPN (most probable number) per 100 ml, and according to the mandatory limits established by the corresponding law in force at each time. Thus, P95 was used for faecal coliform data (European Commission, 1976) and P90 for *E. coli* data (European Commission, 2006). The arithmetic mean ($\bar{x}$) and standard deviation (SD) of log10 were calculated for samples in a yearly basis (1985-2016) and used to calculate the two percentiles (Spanish Government, 2007). The legislation allows the removal of samples that exceed the limit (i) if they do not represent more than the 15% of all the samples for the bathing season, and (ii) are due to short-term pollution. However, for the objective of this study it was considered necessary to maintain all the available data for the calculations.

$$P90 = 10^{\ (\bar{x}\, +\, 1.282\, *\, SD)} \qquad (1)$$

$$P95 = 10^{\ (\bar{x}\, +\, 1.65\, *\, SD)} \qquad (2)$$

For questionnaire results, all the responses were introduced in a data base and analysed using the “stats” package in R environment (R Core Team, 2017). For the different statistical tests performed, a significance level of 0.05 was considered.

The questionnaire results were analysed first all together to check if general tendencies exist in visitors´ perceptions and behaviours; and secondly, separated by beach, to analyse if significant differences exist among beaches. Differences between beaches were tested through Chi-square test for categorical variables and Kruskal-Wallis H test for ordinal variables, then followed by specific *post hoc* tests (Chi-square *post hoc* tests were performed using “fife” package (Fife, 2017) and Dunn´s test of multiple comparisons with Bonferroni corrections were carried out using “dunn.test” package (Dinno, 2017), respectively).

Respondents´ perceptions on water quality changes over time were compared with changes on environmental data, using a logistic generalized linear model (GLM). Beach users perceive visual pollution easier than sewage-derived debris (Roca and Villares, 2008); therefore, this analysis was performed using transparency data and discarding microbial concentration data. To test if correspondence/mismatch between beach visitors´ perceptions and transparency data changes was influenced by socio-economic characteristics, the GLM was built following the next protocol: Firstly, respondents who began to visit these beaches in 2016 (n=37) were discarded. Secondly, a value of transparency change was assigned to each of the remaining respondent. This was calculated as the difference between the most recent transparency value (2016) and the mean value for the period when the respondent first visited the corresponding beach (period (P) 1: 2015-2010; P2: 2009-2001, P3: 1996-2000 and P4: <1996). As transparency data-series started in 1999, no data were available for estimating the value of change for P4. Therefore, based in published literature (Ibarluzea *et al.*, 2000; Bald *et al.*, 2004; García-Barcina *et al.*, 2006) and expert’s consultation, it was estimated that between 2016 and P4, the transparency at the three beaches improved. The dependent variable for the GLM was dichotomous (1: visitors´ perception matched the change in transparency, or 0: there was no match) whereas the explanatory variables included a continuous variable (age) and nine categorical variables (i.e. visited beach, gender, education level, employment status, income, importance of water for aquatic activities, if the visitor practice any aquatic activity in these beaches, current visit-frequency during summer, and level of experience towards the beach (i.e. when they began to visit these beaches)).

To select the model that explains the higher variability with the lowest number of explanatory variables, the next approach was followed: (i) individual GLM´s were built up for each explanatory variable, and if the influence of the corresponding explanatory variable alone was not significant, it was removed from the analysis; (ii) to ensure that multicollinearity among explanatory variables was absent, the variance inflation factor (VIF) technique was used (Zuur *et al.*, 2010), using the "HH" package in R (Heiberger, 2017). The explanatory variable with the highest VIF value was removed sequentially, and the analysis was run again until all the variables had VIF<3; (iii) to make a robust comparison between models, all the incomplete cases (i.e. respondents) were deleted; and (iv) the model with the lowest corrected Akaike Information Criterion (AICc) value was selected, using the "MuMIn" package (Barton, 2016) in R. To check the reliability of the selected GLM against the null model (i.e. model built up without explanatory variables), a Likelihood Ratio Test (LRT) was carried out.

3. Results

3.1. Changes in bathing water quality

Water transparency significantly increased ($p<0.05$) for the period 1999-2016 in the three beaches (Figure A2). There is a gradient in the increase of transparency, from the inner to the outer beach, being more pronounced in Areeta and Ereaga, where the transparency increased >1m.

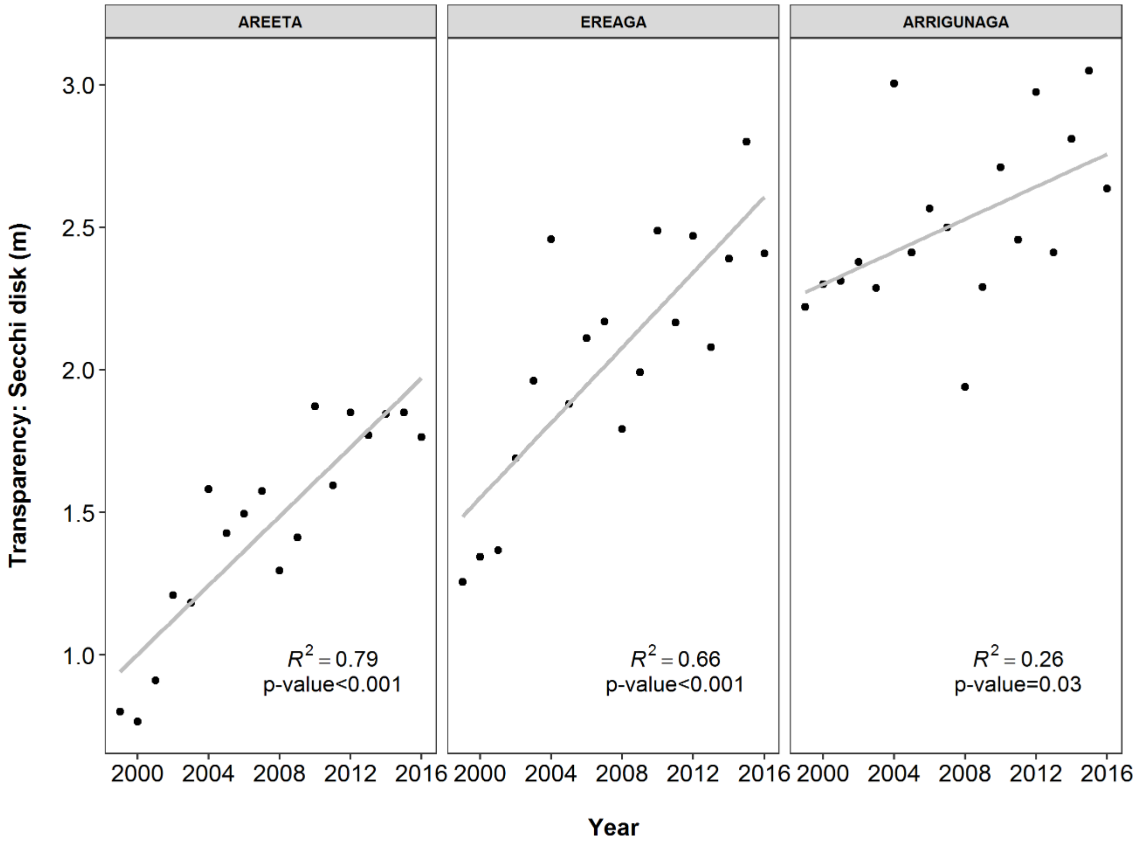


Figure A2 *– Trends of the transparency, measured as depth of Secchi disk, in the surroundings of the three beaches. Grey lines indicate linear regressions.*

Overall, faecal coliforms and *E. coli* concentrations decreased during the 1985-2016 period (Figure A3). While faecal coliform concentration was the indicator used for monitoring microbial concentrations (1985-2007 and 1992-2007 for Ereaga and Arrigunaga, respectively), a significant decrease ($p<0.05$) was observed. The most dramatic decrease in mean annual faecal coliform concentration at Ereaga and Arrigunaga was registered between 2000 and 2003, with punctual rebounds afterwards (in 2004 and 2007). After the approval of more restrictive bathing waters legislation in 2008 and the application of *E. coli* as the microbial indicator (2008-2016), no statistically significant trends have been observed for any of the three beaches. While Ereaga and Arrigunaga have, in most cases since 2001, met the microbial concentrations quality standards (except for 2008 in both beaches and for 2013 in Arrigunaga), the annual mean 90th percentile for *E. coli* has exceed the boundary values in Areeta in three consecutive years (2013-2015) (Figure A3). Areeta, which has only been monitored since 2008, had its highest decrease in microbial concentration during the 2008-2010 period.

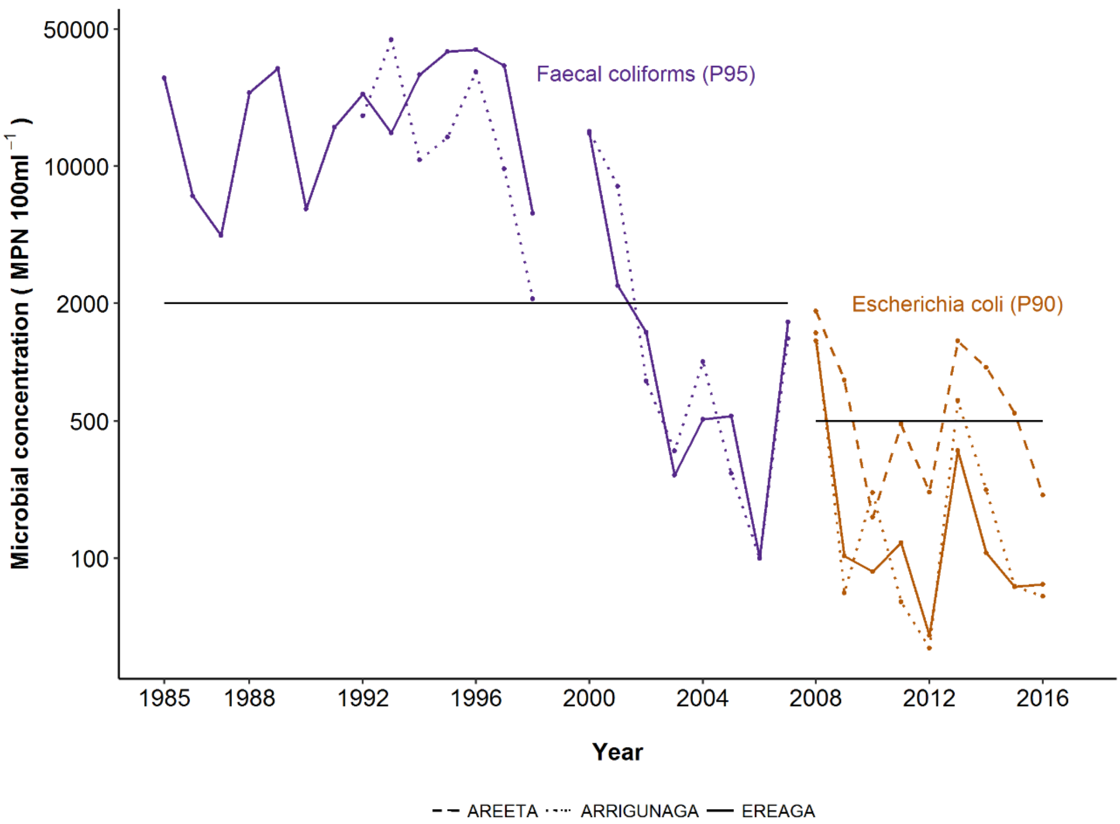


Figure A3 *– Faecal coliform (95th percentile) and Escherichia coli (90th percentile) inter annual concentrations at the three beaches during the bathing season (May-September). Data for the period 1985-1999 were obtained from* (Ibarluzea et al., 2000). *Black lines indicate: From 1985 to 2007, the imperative value of 2000 MPN 100ml^{-1}, according to Directive 76/160/CEE; and from 2008 to 2016, the sufficient quality limit of 500 MPN 100ml^{-1}, according to 2006/7/EC. Note the logarithmic scale in y axis. MPN: Most Probable Number.*

3.2. Questionnaire results

From the 466 sampling trials, a total of 426 questionnaires were successfully completed by beach users (i.e. 91% response rate), 227 in Ereaga, 100 in Areeta and 99 in Arrigunaga).

3.2.1. General profile of beach users and motivations to visit the beach

Respondents were mainly middle-aged (42 ± 16 years), educated (81% completed secondary or higher education) women (74.4%) (Appendix A Table 1). The dominating employment status were "employees" and "self-employed" people (that together constitute the 51.1% of the employment status, with the lowest value in Areeta (46%) and the highest in Arrigunaga (61.7%)) *versus* the other occupancies ("student", “unemployed”, etc.). The three beaches mainly attracted local visitors of the region of Bizkaia, specially from towns surrounding the estuary.

Significant differences ($p<0.05$, see Appendix A Table 1) were found between beaches for gender, education, employment and residence. There were significantly more women in Areeta than in Ereaga, while Arrigunaga was similar in terms of gender to both beaches. Among Areeta visitors, there were more self-employed, homemakers, unemployed and retired people than in the other two beaches. Visitors in the three beaches came from different villages and regions; in Arrigunaga 71.7% of visitors came from Getxo village, while in Areeta, there was a similar proportion of visitors from Getxo and visitors from other villages located along Nerbioi (42% and 48%, respectively). In Ereaga, the biggest group of visitors corresponded to those from other towns located along Nerbioi, while Getxo visitors only represented 19.7%.

The motivations for going to the beach were recorded using a pre-coded question; the three main motivations chosen by Nerbioi beach visitors were sunbathing (86.2%), relaxing & resting (72.8%) and bathing & cooling down in the water (63.8%) (Appendix A Table 2). These three were the main motivations for visiting any of the three beaches.

More than the 75% of respondents considered the possibility of practicing aquatic activities (such as bathing, swimming or surfing) as an essential or important factor when they choose the beach to go (Figure A4); being more important in Arrigunaga (where 86.9% of visitors answered that it was essential or important) than in Areeta (74%) or Ereaga (71.8%). The differences between Ereaga and Arrigunaga were significant (p-value<0.05).

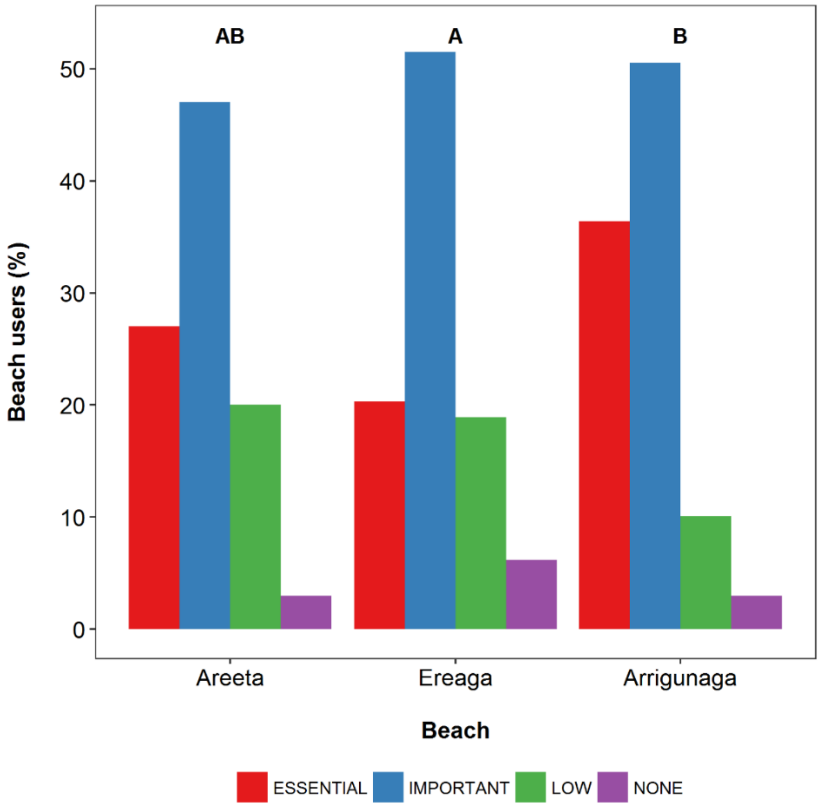


Figure A4 - *Importance given by beach users when choosing a beach to the possibility of practicing aquatic activities. Different lettering (A,B) indicate significant differences between beaches (Dunn´s test with Bonferroni corrections).*

Also, respondents indicated the effect of certain water characteristics in their personal enjoyment of beach aquatic activities (Appendix A Table 3). The most negative effect steamed from the presence of marine debris, followed by water odour, oils in water surface and the presence of wastewater spills nearby; all of them obtained less than 1.2 (negative effect), on a scale of 4 points (where 1=very negative and 4=very positive) (Appendix A Table 3). The factors that obtained higher scoring were both related with the interaction with groups of people, such as the presence of people practicing aquatic sports ($\bar{x}$=2.6 ± 0.72) and the presence of many swimmers in the water ($\bar{x}$=2.45 ± 0.68). Significant differences between beaches (Kruskal-Wallis p-value<0.05) were only found for rocks in the water, as Ereaga and Arrigunaga visitors valued this characteristic more negatively than Areeta visitors (Dunn´s *post hoc* test p-value<0.05).

The main reason provided by respondents for choosing to visit Nerbioi beaches was their proximity to home (nearly 81.9%), followed by their accessibility (34.3%) and their tranquility (31%) (Appendix A Table 4).

Most visitors (88.5%) came to the beach directly from their habitual residence, rather than from work, hotels or others. More than 50% of the visitors in Areeta and Arrigunaga walked to these beaches, whereas to get to Ereaga most visitors went by car (~ 59%) (Appendix A Table 5).

The mean time to arrive to the beaches was 18.3 ± 15 min, while the time spent at the beaches was 3 h 18 min ± 1 h 24 min. The visitors that needed less time to arrive at the beach were Arrigunaga and Areeta visitors (14 ± 13 min and 15 ± 10 min, respectively) (Figure A5(A)); conversely, Ereaga visitors expend significantly more time to arrive at the beach (22 ± 15 min) (Figure A5(B)). The beaches where visitors spend significantly more time were Arrigunaga and Ereaga (3.5 ± 1.5 h and 3.4 ± 1.4 h, respectively). Areeta visitors spent significantly less time in the beach (2.8 ± 1.1 h) than visitors at the other two beaches. The comparison of the travel time and the time spend at the beach (Figure A5(C)) concluded that for each minute expend travelling, Areeta and Ereaga visitors spent significantly ($p<0.05$) less time in the beach than Arrigunaga visitors.

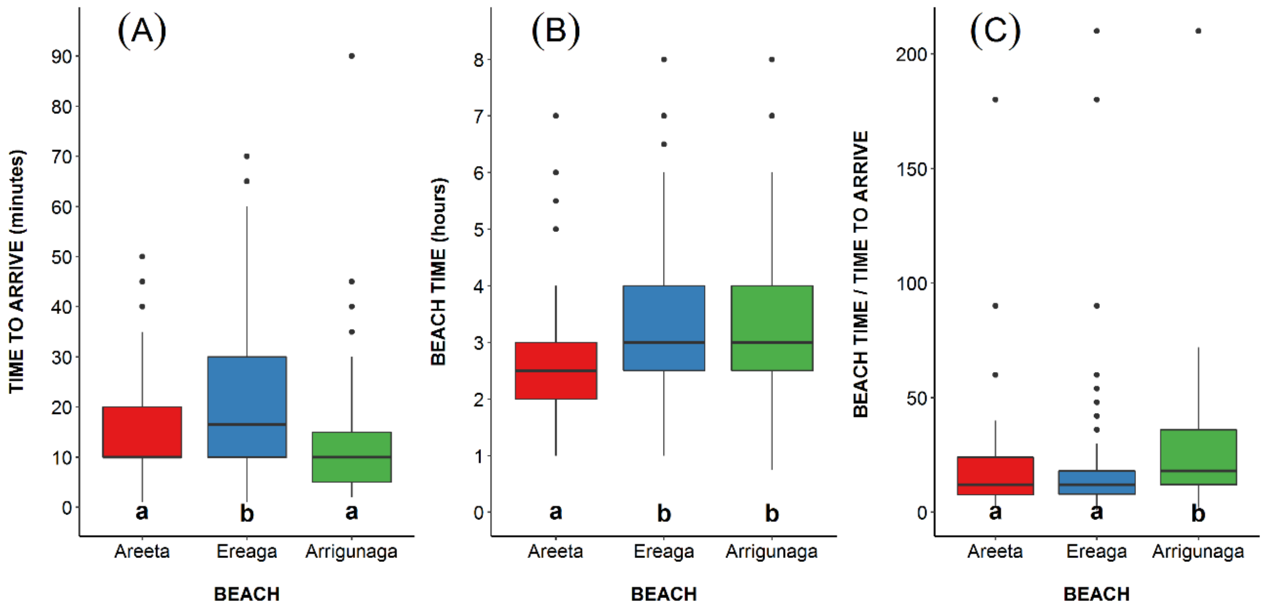


Figure A5 - *(A) Time needed to arrive at the beach; (B) Time expended at the beach. (C) time to arrive – time expend ratio. Different lettering (a,b) below boxes indicate significant differences between beaches (Dunn´s Test with Bonferroni correction p-value<0.05)*

More than 92% of visitors were satisfied or completely satisfied with their visit to the beach in the day of the survey (nearly 88% in Arrigunaga, 90% in Areeta and more than 95% in Ereaga) (Appendix A Table 6). Arrigunaga hold the highest percentage of slightly or not at all satisfied visitors (12.1%).

Around 10% of respondents had started to visit Nerbioi beaches recently (their first visit to that beach was the day when they answered the questionnaire or other day along 2016) (Appendix A Table 7). The rest had a varying experience and knowledge of the beaches: 22.3% had started visiting the beach recently (between 2010-2015) and 28.6% had an intermediate knowledge of the beach (between 7 and 20 years). Overall, 38% of respondents began visiting Nerbioi beaches more than 20 years ago; with the highest percentage corresponding to Arrigunaga respondents, where more than the 44% of visitors to this beach fall under this category.

3.2.2. Valuation of Nerbioi beaches

The percentage of beach users that practice aquatic activities is higher in the two external beaches (65% in Ereaga and 75.8% in Arrigunaga) compared to Areeta (44%) and the difference is statistically significant (for both Chi-square tests (Areeta vs. Ereaga and Areeta vs. Arrigunaga), p-value always <0.05). For the visitors that did not practice any aquatic activity in these beaches, the (poor) water quality was the more frequently mentioned reason (16.7% in Ereaga, 33.9% in Areeta and 45.3% in Arrigunaga). However, from the respondents that did not practice any aquatic activity in these beaches (n=158), more than 63.9% indicated that the possibility of practicing aquatic activities is essential or quite important when they choose which beach to visit. Furthermore, from those 158 respondents, 80 (50.6%) claimed that practicing aquatic sports and/or bathing was one of the main motivations to go to any beach.

When visitors were asked to value a set of 29 beach characteristics, the ones related with the general conditions of the beaches, such as safety (3.2), accessibility (3.1) and tranquillity (3.0) obtained the highest scores, in a scale that ranged from 1 (bad) to 4 (excellent) (Appendix A Table 8). The characteristics that obtained the lowest valuation were the facilities for practicing sports, opportunities for practicing recreational activities and shade availability (all of them $\bar{x}$ =1.5). All the characteristics related with bathing waters obtained average scores between 2.0 and 2.9 (2=moderate and 3=good); water quality and water odour were valued significantly lower in Areeta than in the other two beaches (Dunn´s Test p-value<0.05). Between Ereaga and Arrigunaga, the differences in water were less evident, as they obtained similar valuation for most of the characteristics (Dunn´s Test p-value>0.05 for water quality, water odour, water temperature, sea currents, jellyfish and oils in the water). There is a trend of decreasing scores from inner to outer beaches with significant differences (Dunn´s test p-value<0.05) for some water related characteristics, such as rocks, waves, sea currents, presence of jellyfish and presence of seaweeds, branches and plant debris.

Areeta visitors had different perceptions regarding the potential health effects of bathing in the beach (Chi-square *post hoc* test for both Areeta vs. Ereaga and Areeta vs. Arrigunaga, p-value<0.001). Indeed, in Areeta, the same number of visitors (20) believe that bathing had a positive and negative effect. In contrast, visitors who believe that the effect in health was negative was relatively low in Ereaga (8 out of 201) and in Arrigunaga (4 out of 86). The percentage of visitors who believed that bathing in these beaches had a positive effect decreases towards the inner estuary, when comparing with the total number of visitors in Table A1 (43% in Arrigunaga, 32% in Ereaga and 22% in Areeta).

Table A1 *– Chi-square test of homogeneity of Nerbioi beaches, regarding visitors´ perceptions on the potential health effects of bathing at these beaches (positive effect, negative effect or no effect on health). The test was performed comparing observed and expected frequencies. Key: (n) observed frequencies, (ef) expected frequencies, (***) significant differences (p<0.001) after Chi-square test.*

	Areeta n (ef)	**Ereaga n (ef)**	**Arrigunaga n (ef)**	**Chi-square X^2**
Positive effect	20 (29.1)	65 (65.0)	37 (27.8)	**33.756 *****
Negative effect	20 (7.6)	8 (17.1)	4 (7.3)	
No effect	50 (53.2)	128 (118.9)	45 (50.9)	
Total	**90**	**201**	**86**	

3.2.3. The view of experienced visitors: Changes in beaches and ecosystem services

The number of experienced visitors (i.e. those respondents that started to visit the beaches before 2010) were 66.7% of the total (Appendix A Table 7) and they had to answer additional questions regarding their perception of changes on the number of visitors, changes in bathing water quality and perception on the provision of ecosystem services. The likelihood that these visitors will stop visiting these beaches if any of the characteristics worsened was also explored.

Table A2 *– Chi-square test of independence for visitors´ perceptions of changes in bathing waters (improved, worsened or no change) and the year when they started to visit Nerbioi beaches (2010-2015, 2001-2009, 1996-2000 or ≤1995). The test was performed comparing observed and expected frequencies. Key: (n) observed frequencies, (ef) expected frequencies, (***) significant differences (p<0.001) after Chi-square test.*

	New visitors	**Experienced visitors**			**Chi-square**
	2010-2015 n (ef)	**2001-2009 n (ef)**	**1996-2000 n (ef)**	**≤ 1995 n (ef)**	X^2
Improved	40 (68.8)	53 (52.3)	35 (33.6)	147 (120.3)	**89.446*****
Worsened	8 (6.3)	6 (4.8)	0 (3.1)	11 (10.9)	
No change	44 (17.0)	11 (12.9)	10 (8.3)	3 (29.8)	
Total	**92**	**70**	**45**	**161**	

The level of experience of visitors influenced their perception of changes in bathing waters quality (Table A2). Among new visitors (first visit 2010-2015) a similar percentage perceived an improvement and no change in bathing waters quality, while among the most experienced visitors (first visit ≤1995) the 90.7% perceived an improvement in water conditions. The percentage of visitors who perceived the improvement increases with experience, while the percentage of visitors who did not perceive any change decreases (Table A2). The Chi-square test of independence revealed association between the year when the visitors started to visit Nerbioi beaches and their perception of changes in bathing waters (Chi-square test $p<0.001$) (Table A2). According to the Chi-square *post hoc* test, visitors with the longer experience have the most positive perception of changes in bathing waters, while those who began coming to these beaches more recently have a more negative perception of changes (Chi-square *post hoc* test $p<0.05$).

The majority of experienced visitors in all beaches (82.7%) perceived an improvement in water quality (Appendix A Table 9). The visitors who perceived water as being in better conditions linked the improvement mainly to: (i) water sanitation in Nerbioi estuary (60-80% of visitors); (ii) tightening of the laws related to water quality and wastewater spills (54-59% of visitors); and (iii) to a higher investment by public bodies in beach cleaning (41-55% of visitors). Also, for most visitors that perceived an improvement in water quality, this positive change was essential or very important for deciding to come to these beaches (79.6% in Areeta, 89.7% in Ereaga and 93.3% in Arrigunaga).

Most experienced visitors perceived that the number of users had mainly increased or highly increased (74.7%) at the beach where they were interviewed (Appendix A Table 10).

Nearly 80% of experienced visitors agreed that Nerbioi beaches provided ecosystem services to visitors (Appendix A Table 11), with the highest percentage corresponding to Ereaga respondents (83.3%) and the lowest to Areeta respondents (66.1%). In Areeta, the percentage of visitors who believe that the beach provided ecosystem services was significantly lower than in the other two beaches (Chi-square *post hoc* test p-value<0.05, for both comparisons).

The likelihood of change in experienced visitor´s behaviour was also explored by questions were respondents indicated if they would stop visiting these beaches if certain characteristics worsened (Table A3). The hypothetical scenarios revealed that the highest probability (on a scale from 1= not probable to 4=sure) to stop visiting these beaches would be driven by deterioration of water characteristics. Mean scores ranged between 3.32 and 3.60 for the different features, being “if marine debris increases” and “if bathing was forbidden due to the poor water quality”, the features with highest potential negative impact. For some water deterioration hypothetical scenarios (i.e. increase in marine debris, increase of oils spills and prohibition of bathing due to the poor water quality), the mean probability scores were significantly higher among Arrigunaga and Ereaga visitors than among Areeta visitors (Dunn´s test p-value<0.05) (Table A3).

***Table A3** - Probability to quit visiting Nerbioi beaches if status of certain characteristics changes. Mean and standard deviation (SD) values estimated for a scale from 4 (=sure) to 1 (=not probable). Significant differences after Kruskal-Wallis test are indicated as *p<0.05; **p<0.01; ***p<0.001. Different lettering (A,B,C) in the mean values indicate significant differences between beaches (Dunn´s test with Bonferroni correction p-value<0.05).*

	Areeta		**Ereaga**		**Arrigunaga**		**TOTAL**		**Kruskal-Wallis (H)**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Water characteristics									
More jellyfish and harmful species	3.02	1.13	3.40	0.72	3.38	0.73	3.32	0.83	3.451
Water odour gets worse	3.30	0.87	3.61	0.58	3.61	0.59	3.55	0.66	6.284
Increase of marine debris	3.31 ^{A}	0.88	3.67 ^{B}	0.60	3.71 ^{B}	0.56	3.60	0.67	**11.394****
Increase of foams on the water	3.14	0.97	3.38	0.78	3.45	0.71	3.35	0.81	3.369
More oil spills in the water	3.22 ^{A}	0.96	3.65 ^{B}	0.62	3.63 ^{B}	0.63	3.56	0.72	**11.497****
Bathing forbidden due to poor water quality	3.10 ^{A}	0.99	3.70 ^{B}	0.60	3.73 ^{B}	0.58	3.59	0.73	**24.998*****
Other beach characteristics									
Installations get worse	2.62	0.99	2.71	0.87	2.63	0.91	2.67	0.90	0.449
Security services get worse	2.64	0.99	2.86	0.84	2.75	0.83	2.78	0.87	2.189
Number of visitors increases considerably	2.46	0.83	2.55	0.79	2.72	0.93	2.57	0.84	3.096
Increase of rubbish on the sand	3.46	0.60	3.56	0.57	3.59	0.52	3.55	0.57	1.904
More people practicing aquatic sports	2.20	0.91	2.10	0.81	2.07	0.78	2.11	0.82	0.598
Increase of maritime traffic	2.44	0.87	2.47	0.87	2.37	0.74	2.44	0.84	0.606

3.3. Water quality change perceptions versus recorded changes in environmental variables

From the ten explanatory variables analyzed, five (age, gender, employment status, if the visitor practices any aquatic activity in these beaches, and level of experience towards the beach (i.e. when they began to visit these beaches)) had individually a significant effect in the dependent variable (match/mismatch between visitors´ perception and the change in transparency), and therefore, were used on the VIF analysis. The VIF analysis resulted in VIF values < 3 for the six preselected variables, and therefore all of them were used at the next step for the GLM selection. The model with the lowest AICc and therefore, the best logistic GLM to explain the chance that visitor´s perception on the changes occurred in the water quality is correct, was built up with one explanatory variable: the level of beach-experience of the visitor (Table A4). In short, the level of beach-experience had a remarkable effect on visitor´s perception accuracy towards changes in water quality (represented as the change on water transparency), as those with longer time visiting Nerbioi beaches perceived better the positive change that occurred in water quality than those who started visiting these beaches more recently.

The intercept (Table A4) includes the effect of respondents that began to visit the beach after 2009. The value of the estimate increases with a longer experience of the beach, indicating that as the number of years visiting these beaches increases, so does the chance that the visitors´ perception towards change in water transparency will be more accurate.

Table A4 - *Logistic GLM for exploring the influence of socioeconomic factors in the chance that visitors guessed the change in water quality. Key: (AICc) corrected Akaike Information Criterion, (LRT) Likelihood Ratio Test for the null model against the selected model. Significant correlations for LRT are indicated as *p<0.05; **p<0.01; ***p<0.001, and in bold for Z value.*

	Estimate	**SE**	**Z value**	**Pr (>|z|)**	**AICc**	**LRT (χ^2)**
GLM1: Change on water quality by transparency (n=368)						
(Intercept)	-1.22	0.25	-4.90	**<0.001**	327.363	133.02***
Experience (2001-2009)	2.36	0.37	6.31	**<0.001**		
Experience (1996-2000)	2.47	0.44	5.67	**<0.001**		
Experience (≤1995)	3.57	0.37	9.54	**<0.001**		

4. Discussion

The improvement of ecological factors such as water quality through coastal restoration can have a remarkable positive effect in marine ecosystem services and human well-being (Elliott *et al.*, 2007). However, much is yet to be explored to have a complete comprehension on this topic.

In Nerbioi estuary, management measures (i.e. WWTP, including biological treatment) aimed at reverting the previous degraded ecological situation (García-Barcina *et al.*, 2006) have resulted on environmental changes, and more specifically, in better bathing water conditions of beaches, attracting more visitors. As shown in this chapter, the decrease in microbial concentration since 1985, and especially after 2001 with the beginning of the biological treatment in the WWTP (Pascual *et al.*, 2012), has resulted in the compliance with bathing waters´ legislation (European Commission, 2006; Spanish Government, 2007). In addition, the aesthetic conditions, such as water transparency, also improved, making bathing waters in these beaches more attractive (after users' perceptions). After these results, summarized in Table A5, a global recovery has been achieved in the estuarine environmental factors, with a general gradient from the inner (more intense) to the outer part of the estuary. Areeta, being the most inner beach and relatively close to the WWTP discharges (García-Barcina *et al.*, 2006), is the beach with the worst bathing water conditions.

Table A5 *- Summary of the main findings of the study, related to the recovery of the quality in the estuary, in the three studied beaches, and the associated perception of the respondents to the survey, on the improvement of the system and the ecosystem services provided. Note: depth in brackets mean the increase of Secchi depth over the initial depth in the area; (-) means that although the bacteria concentration has decreased, sometimes the values are still over the quality standards.*

	Areeta	**Ereaga**	**Arrigunaga**
Gradient	***Inner***	***Middle***	***Outer***
Environmental factors			
Transparency (2000-2016)	↗ (1.5m)	↗ (1m)	↗ (1m)
Microbiology (1985-2016)	↘ (-)	↘	↘
Perceptions and ecosystem services			
Answered by all visitors (n=426)			
• Practicing aquatic activities (all visitors)	44%	65%	76%
• Positive health effects of bathing (all visitors)	22%	32%	43%
• Fully or mostly satisfied visitors with beach trip (all visitors)	90%	95%	88%
• Water quality valuation (1=bad, 4=excellent) (all visitors)	2.00	2.47	2.34
Answered by experienced visitors (n=284)			
• Perceived increase in number of users (1985-2016)	76%	68%	87%
• Perceived improvement in bathing water quality	83%	84%	80%
• Water quality improvement (1985-2016) as reason to come	80%	90%	93%
• This beach is providing ecosystem services	66%	83%	83%
• Not coming back if water deteriorates (1=not probable, 4=sure)	3.1	3.7	3.73

The questionnaire results suggest that water quality improvements are perceived by visitors, and perceptions were more accurate among those who have visited the beach for many years. The improvement stated by visitors might not only be due to their visual perception of water (i.e. increase in water transparency) but also due to their personal knowledge of the sanitation status of the waters. Indeed, bathing was forbidden for many years in the three beaches (Ibarluzea *et al.*, 2000; AZTI, 2011) and the more experienced visitors (~38% visited any of the beaches for >20 years) probably remember past conditions. Also, they reckoned that the main cause for the improvement of bathing water was the sanitation of the estuarine waters, which is a direct consequence of the WWTP (Borja *et al.*, 2010a; Cajaraville *et al.*, 2016). The perception also matches the recovery gradient of the estuary, with an increased percentage from inner to outer estuarine beaches, of respondents who estimate that bathing in these beaches has a positive effect on health (Table A5). Furthermore, the worst perception of bathing waters among Nerbioi beaches corresponded to the innermost beach (i.e. Areeta), which received the lowest valuation for water-quality-related characteristics (e.g. water quality and water odour). Indeed, bathing was forbidden in this beach for more years than in the other two beaches, until 2009 (AZTI, 2011).

Water conditions are valued as an important factor to beach visitors (Roca and Villares, 2008) and can affect visitors behaviour and perceptions towards the beach. Indeed, Nerbioi beach visitors answered that the possibility of practicing water activities is a motivational factor for them to go to the beach, and water quality conditions are considered when deciding which beach to visit. Again, data on the percentage of people who practice aquatic activities in these beaches followed an increasing pattern from inner to outer estuary (Table A5), and this result goes in line with the pattern observed in the environmental conditions. However, legislation determines bathing waters suitability through microbial concentration monitoring, while bathers' perceptions on water conditions are governed, mainly, by their direct visual experience (Bonaiuto *et al.*, 1996). Thus, beach users in Nerbioi considered characteristics such as water aesthetics and cleanliness conditions when determining the bathing waters quality. After these findings, bathing waters´ characteristics related with water cleanliness (e.g. marine debris, oils, odour and wastewater spills nearby) had a more important effect on visitors´ enjoyment of aquatic activities than other water variables (e.g. water temperature, presence of rocks or strong waves) or than the interaction with other bathing water users (e.g. people practicing water sports, other swimmers). Furthermore, most experienced visitors indicated that they would not go back to Nerbioi beaches if bathing was again forbidden due to poor water quality, with an increasing probability pattern from the inner to the outer estuary. Also, among the respondents who perceived an improvement in waters conditions, the perceived improvement was a determining factor for most of them to choose to come to these beaches, again with an increasing pattern from the inner to the outer beaches (Table A5).

Considering the importance placed to water quality variables by beach users and the reported environmental improvement in bathing water, it could be expected an increasing number of beach visitors (Kreitler *et al.*, 2013). In fact, respondents considered that the number of users highly increased between 1985 and 2016 in Nerbioi beaches (Table A5). The good scores obtained by the interaction with other recreationalists (i.e. bathers, people practicing aquatic sports) suggest that the perceived increase in visitors has not supposed yet a feeling of overcrowding in beach occupancy, which can degrade the recreational experience (Saveriades, 2000; Roca *et al.*, 2008).

Also, survey respondents believed that Nerbioi beaches were areas that provide ecosystem services, with an increasing gradient from the inner to the outer Nerbioi (Table A5). This gradient in the perception of the ecosystem service provisioning can be based upon the differences found in the bathing waters quality, as demonstrated elsewhere (Kreitler *et al.*, 2013).

Although the current study showed that the estuarine waters sanitation had positive consequences in both bathing waters conditions and beach users´ perceptions, a small percentage of respondents indicated that the quality of the water is still poor. The negative perception of water quality was pointed out by visitors who do not practice aquatic activities as the main reason for not doing so, as already found in Los Angeles (Pendleton *et al.*, 2001). In Nerbioi, this negative perception can be influenced by the memory of the past water pollution, which is affecting the capacity of current visitors to enjoy aquatic activities, even with more appealing water conditions than in the past. Most of the people who did not practice water activities in these beaches admitted that they considered the possibility of practicing aquatic activities as an important factor when choosing the beach to go, and half of them argued that practicing aquatic activities was one of the main motivations to go to a beach.

The fact that not all the Nerbioi beach users noticed improvements in water quality proved that past bad environmental conditions are difficult to fully perceived as overcome, even when recorded data indicate a clear ecological recovery. That is, the flow from environmental recovery to a tangible provision of ecosystem services is not easily perceived. In this study, it has been also found that although water quality conditions are considered by users when choosing the beach to go, this factor is not the main one and has a low importance in beach user´s general satisfaction. Therefore, this study confirms that considering only ecological conditions as indicators of recovery of cultural ecosystem services is not sufficient (Ziv *et al.*, 2016). Indeed, all these findings reinforce the idea that cultural ecosystem services are composed by both environmental and sociocultural factors (Reyers *et al.*, 2013).

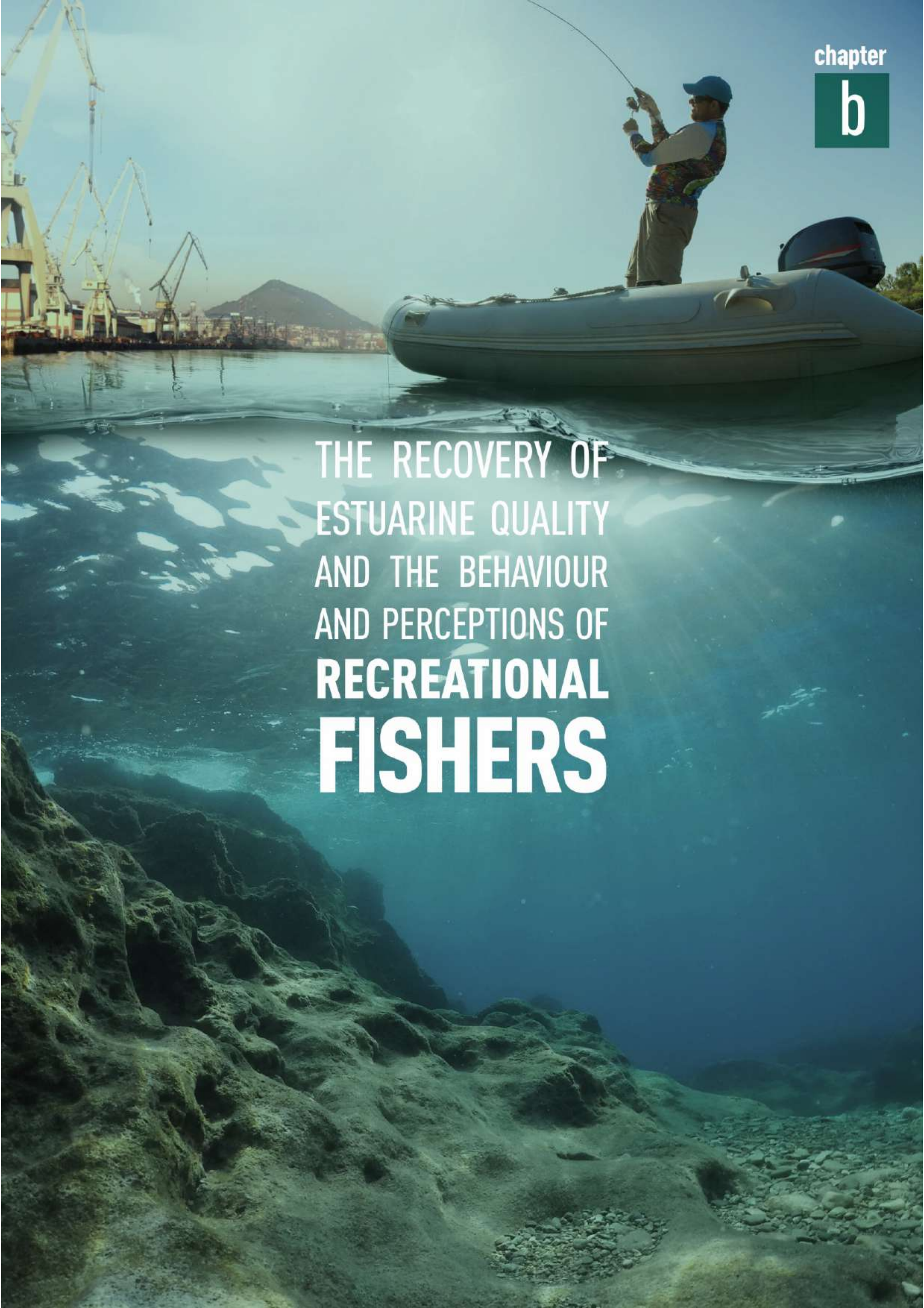
A restored environment can only be linked to better provisioning of cultural ecosystem services if people perceive an improvement in the benefits they derive from the restored ecosystem, as well as an increase in their experience and satisfaction. Indeed, user´s perceptions in ecosystem service valuation is considered crucial (De Groot *et al.*, 2002, 2010) and necessary to arrive to a real integrated ecosystem services valuation (Garcia Rodrigues *et al.*, 2017) that can be useful for the development of good management actions for preservation of marine ecosystems and their services (Barbier, 2017).

5. Conclusions

In Nerbioi estuary, the implementation of the WWTP increased the transparency of waters and decreased the faecal microbial inputs into the estuary, leading to a healthier environment and increasing recreational opportunities in local beaches (i.e. an increase in the capacity to provide cultural ecosystem services). Thanks to a healthier environment, Nerbioi beaches hold nowadays higher potential to attract visitors than 25 years ago. Furthermore, the findings of this study suggested that generally, both ecological recovery and beach user´s perceptions and behaviour, follow the same pattern from the inner to the outer estuary, finding better bathing conditions and a more positive attitude towards bathing waters in the outer than in the inner beaches. The improvement of ecological conditions reported benefits to society in Nerbioi, creating (or recovering) recreational opportunities, but a step further in ocean literacy and awareness is needed for full ecosystem services restoration recognition, where environmental improvements can be perceived and positively valued by all users. Policy-makers and managers should consider both (i) ecological restoration as means to improve ecosystem services provision and (ii) awareness raising campaigns so the recovery of ecosystem services can be valued by users.

chapter

b



THE RECOVERY OF ESTUARINE QUALITY AND THE BEHAVIOUR AND PERCEPTIONS OF **RECREATIONAL FISHERS**

Abstract

Well-functioning ecosystems hold high values of biodiversity and provide a wider range of ecosystem services. In 25 years, Nerbioi-Ibaizabal estuary (North Spain) has changed from a highly polluted estuary to one with a moderate/good ecological status, mainly due to the settlement of a WWTP that has operated in the estuary since 1990. In recent decades, recorded biotic and abiotic parameters show a clear ecological improvement, but the concurrent response of cultural ecosystem services (e.g. recreational fishing) remains unexplored. Recreational fishers' fishing behaviour and perceptions over environmental changes were obtained through a questionnaire and compared with recorded parameters of improvement. Results show a positive correlation between the abiotic ecological recovery and fishers' behaviour. However, fishers´ perceptions on the biotic recovery (e.g. fish abundance) were more negative than those recorded. Despite this, fishers are satisfied with the overall experience of fishing and will probably continue fishing in the estuary. In conclusion, in better functioning estuaries the capacity to deliver cultural services (e.g. recreational fishing) increases. However, getting ecosystem services to the level of appreciation of society requires to be much better communicated.

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1. Introduction

Estuaries play an essential role, being a focal point for maritime transport, a producer and supplier of natural resources and an important area for practicing recreational activities (Barbier *et al.*, 2011). Forty-three percent of the world's population lives no further than 50 km from an estuary (O'Higgins *et al.*, 2010). However, estuaries have been historically degraded by human activities (Lotze *et al.*, 2006), leading to loss of quality and ecological status of these systems (Lotze, 2010; EEA, 2012), and consequently, affecting their capacity to deliver ecosystem services (Barbier *et al.*, 2012).

Over recent decades, restoration projects have been implemented in estuarine environments in order to halt degradation (Elliott *et al.*, 2007) and improve ecosystem functioning, structure and biodiversity. Several reviews have investigated the recovery of these environments from degradation (Borja *et al.*, 2010a; Verdonschot *et al.*, 2013; Duarte *et al.*, 2015). In those reviews, the assessment of restoration success is based on changes in aspects of the ecosystem such as functioning, structure and/or biodiversity. Even if there is a general agreement on the ability of ecological restoration to improve biodiversity, achieve good ecological status, and increase the provision of ecosystem services (Bullock *et al.*, 2011; Everard, 2012), the way in which ecosystems function and processes deliver ecosystem services is still not well understood (Costanza *et al.*, 2017).

Ecosystem services are defined as the benefits that humans derive, directly or indirectly, from ecosystem functions (Costanza *et al.*, 1997). From the three categories of ecosystem services (i.e. provisioning, regulating/maintenance, and cultural) (Haines-Young and Potschin, 2013), cultural services are those that provide recreational, aesthetic, spiritual and educational benefits to society (Hernández-Morcillo *et al.*, 2013) being recreational services those most commonly assessed (Liquete *et al.*, 2013). Recreational fishing is considered a cultural service of marine (Ghermandi *et al.*, 2012), and freshwater ecosystems. Fishing is considered recreational when "fishers do not sell the fish they catch", and when it "is not undertaken for predominantly subsistence purposes…"; usually, it is performed by catching fish on hooks, but "may include the use of small boats, the capture of fish by divers with spear guns and hand-gathering of shellfish from the beach or shore" (Pawson *et al.*, 2008). Therefore, recreational fishing is a consumptive cultural service (Ghermandi *et al.*, 2012), even if the main motivations for practicing recreational fishing are usually non-catch related rather than catch-related (Fedler and Ditton, 1994; Robertson and Caporossi, 2003).

Measuring changes in activities, such as recreational fishing, could be a way to determine the consequences of restoration in terms of social benefits. However, the approaches to measure and understand the relation between restoration and the provisioning of cultural ecosystem services is still limited (Aronson *et al.*, 2010; Abelson *et al.*, 2016; Boerema and Meire, 2017). This limitation is more aimed at marine ecosystems, where restoration examples and research on ecosystem services remain under-represented in comparison with terrestrial ecosystems (Borja *et al.*, 2015), even when monitoring, assessment and evaluation of ecosystem services in these environments is considered critical for improving both management and policy designs (Borja *et al.*, 2016a).

When monitoring estuaries, changes in fish abundance, richness, fish size, etc., could be straightforward biological variables to measure the effects of restoration actions (Williams and Zedler, 1999; Sheaves *et al.*, 2012). These measured effects may or may not be appreciated by those fishing in the area. To demonstrate this appreciation, it is necessary to show that humans benefit somehow from those improvements and are satisfied (Uyarra *et al.*, 2010; Costanza *et al.*, 2017). Collecting data on fisher´s perceptions and behaviour could serve to assess the effects of restoration measures on recreational fishing activities. Recreational fishers' opinion has been successfully used in conservation and management (Granek *et al.*, 2008), in the habitat valuation of restored areas (Fulford *et al.*, 2016); for analysing attitudes towards marine protected areas and fishing grounds (Robertson and Caporossi, 2003; Sutton and Tobin, 2009; Martin *et al.*, 2016; Szostek *et al.*, 2017); for legislation implementation and conservation efforts (Cook *et al.*, 2015); and for the monitoring of recreational fishery activity (Barrella *et al.*, 2016).

The overall objective of this study is to test whether recreational fisher´s perceptions and behaviour in the restored Nerbioi-Ibaizabal estuary (from now onwards, Nerbioi estuary) (Figure B1), combined with abiotic and biotic data, can be used to determine changes in the provisioning of cultural ecosystem services such as recreational fishing. This objective is divided into three sub-objectives: (i) to determine if, after the ecological recovery of the estuary, attributes important to recreational fisheries (i.e. fish abundance) and attributes of the recreational fishing activity (i.e. number of recreational fishing licences) have improved accordingly; (ii) to determine if recreational fishers´ behaviour changed after the ecological recovery of the estuary; and (iii) to assess the perceptions of recreational fishers towards the recovery of the estuary.

2. Methods

2.1. Study area

In Nerbioi, the implementation of the WWTP, together with the extensive industrial decline in the area, led to a progressive recovery of the estuary, from the toxicological point of view (Cajaraville *et al.*, 2016). The estuary has been extensively monitored since 1989 showing a progressive recovery, from the external to the inner estuary, of biological elements and an increasing value of biodiversity (Borja *et al.*, 2010a; Pascual *et al.*, 2012), despite other potential degrading factors, such as the progressive enlargement of the commercial port in its external part in the last decades (Grifoll *et al.*, 2013). In order to study the recreational fishing activity along the Nerbioi, the estuary was divided into five segments (SEG): SEG1 and SEG2 correspond to the outer part of the estuary, whereas SEG3, SEG4 and SEG5 correspond to the inner part (Figure B1). The segments were defined according to existing sampling stations of the monitoring programmes; which had been established to obtain representative data along the salinity gradient of the estuary.

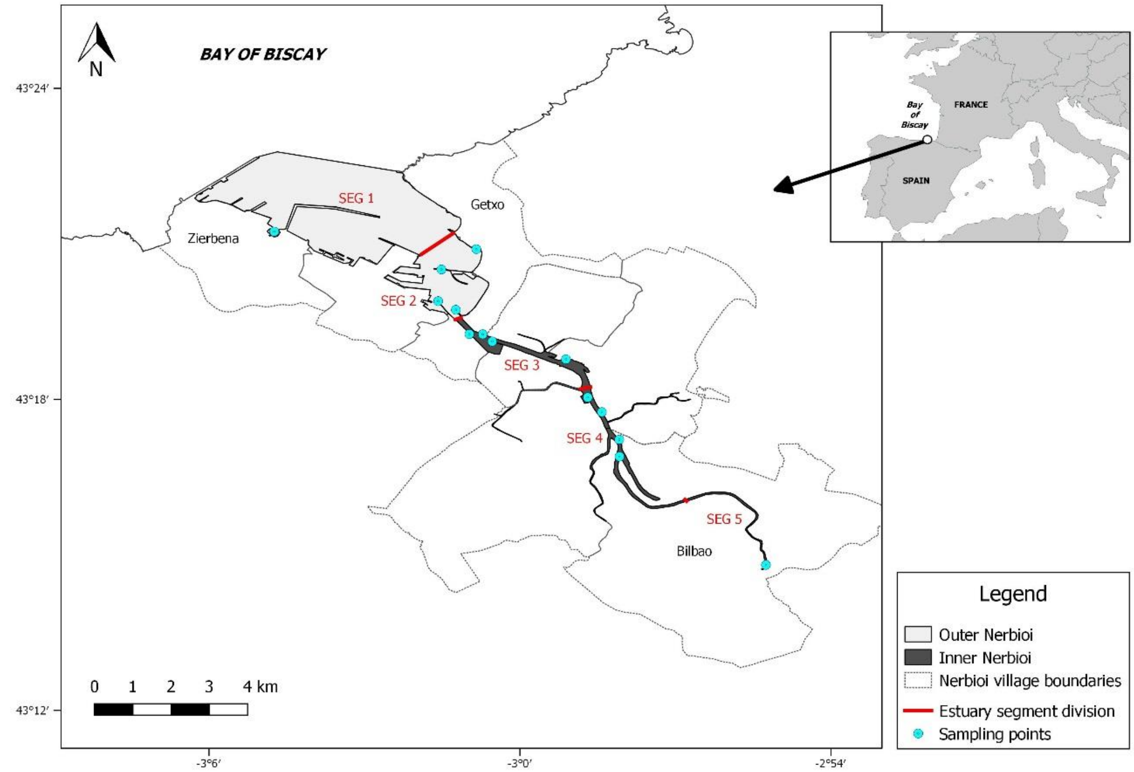


***Figure B1 -** Estuary division in segments (SEG) and the fishing spots visited for the in situ sampling (sampling points).*

2.2. Assessment of the estuarine restoration

For understanding whether ecological recovery translates into changes in recreational fishing, three sources of information were used: (i) monitoring data from the Basque Water Agency (Borja *et al.*, 2016b) and Bilbao-Bizkaia Water Consortium (García-Barcina *et al.*, 2006), for the periods 1994-2015 and 1989-2015, respectively; (ii) data from an annual recreational fishing competition organized by the regional on-shore fishing federation (1992-2015), and (iii) recreational fishing licences issued for the area (1999-2015) by the Basque Government. All these data sets are hereafter referred as “recorded data”.

The monitoring programmes covered abiotic (i.e. oxygen saturation and ammonium concentration) and biotic variables (i.e., demersal fish abundance (total and by species) and demersal fish richness). Oxygen saturation in the bottom layer and ammonium concentration in the surface were chosen as water quality indicators, as they are linked to the recovery of the fauna in the estuary (Borja *et al.*, 2006, 2016b) and, especially, to the recovery of fish and their ecological status (Uriarte and Borja, 2009).

Data series on these two variables have existed since 1994; details on sampling frequency and analysis methods are described in Uriarte and Borja (2009) and Borja *et al.* (2016b). Demersal fish abundance and richness were derived from the annual survey carried out since 1989, with the methodology already described by Uriarte and Borja (2009). The annual fishing competition was organized in SEG3, having data on the number of participants, number of captured fishes and total weight of the catches. For each year, and, as an approximation to estimate the changes in fish size, the total weight of the catches was divided by the number of catches. Finally, the number of recreational fishing licences (on-shore and spearfishing), issued for people living at the estuarine villages, was used as an indicator of recreational fishing patterns. The number of active licences per year was calculated taking into account that the spearfishing licences are valid for a period of one year and the on-shore fishing licences for a period of five years (Basque Government, 2000).

2.3. Characterization of the recreational fishing activity

A questionnaire was designed to investigate recreational fishers´ behaviour and perceptions in the estuary. The design followed the FAO guidelines (Crawford, 1997) and was based on previous studies for the characterization of recreational fishing communities in different countries (Arlinghaus and Mehner, 2003, 2004; Arlinghaus, 2006; Zarauz *et al.*, 2015). In order to obtain the final design, structure and content, the questionnaire was tested in December 2015 with 10 researchers and technicians and in January 2016 with 11 anglers.

The final questionnaire was written in Spanish and comprised 29 types of questions (i.e., pre-codified, presence-absence questions, ranking, Likert-score and open-ended questions) and was structured into five sections: (i) socio-economic profile of the fishers; (ii) main fishing habits; (iii) differences in fishing habits between estuary segments; (iv) opinion of fishers about the fishing activity; and (v) perceived changes over time. The complete questionnaire is presented in Appendix B1.

To characterise the profile of the recreational fishers, the questionnaire included socio-economic questions (i.e. gender, age, home address, education and employment status), and questions on their recreational fishing experience (years of fishing experience and main motivations (up to 3 responses)). To characterise the fishing activity, fishers answered specific questions about their fishing experience inside the estuary. For each of the estuarine segments, respondents had to indicate whether they have ever fished there and, if so, when was the first time (i.e. year of the first fishing event). If fishers still fish in the segment at present, they indicated their fishing methods and the most frequently caught species (i) when they began fishing in that segment, and (ii) at present. Likert-score type questions were used to capture perceptions over changes in six variables potentially influencing fishers´ decision to fish in Nerbioi (i.e. abundance of catches, the variety of caught species, catches size, number of recreational fishers, water quality and personal satisfaction towards the fishing activity). Finally, with the aim of identifying the key aspects that could have improved the quality of the recreational fishing activity, respondents indicated the importance they placed on 20 characteristics when they decide where to fish, and the perceived current condition of such characteristics in the entire estuary.

Two approaches were used to distribute the questionnaire: (i) on-site face-to-face interviews with people fishing in the estuary (*in situ* sampling); and (ii) contacting fishing clubs and federations (*ex situ* sampling). For the *in situ* sampling, the first step was to visit the fishing banks and detect the most popular spots and best times of the day to capture the higher concentration of anglers (November-December 2015). Afterwards, from January to September 2016, one interviewer (the author) carried out the face-to-face interviews, visiting a total of 14 fishing spots (1-4 spots per segment) (Figure B1). The interviewer stayed at the fishing spot between one and five hours, depending on the number of present anglers. This sampling procedure was especially appropriate to collect answers from shore anglers. In every sampling event, the interviewer also recorded the date, time and number of anglers when arriving and leaving the fishing spot, number of survey trials and number of distributed questionnaires.

For the *ex situ* sampling, 14 fishing associations and three fishing Federations were contacted (April-September 2016), to obtain information from spear fishers and those that fish from boats in the estuary. The interviewer explained the questionnaire to one or various members of the clubs and federations who later distributed the questionnaires among interested fishers. In those cases, the questionnaire was filled in by the respondent, without the presence of the interviewer. A variable number of questionnaires (1-25) were distributed to each club or federation.

2.4. Data analysis

Data were statistically analysed in R language (R Core Team, 2017). For the assessment of the estuarine restoration, temporal trends of the recorded data were analysed using linear regressions. For characterizing the fishing activity, exploring the changes registered over time and analysing if significant differences exist across segments, different non-parametric test were used. The socio-economic aspects captured through the questionnaires were tested for exploring differences between *in situ* and *ex situ* samplings. Three non-parametric tests were used, depending on data type: Fisher´s exact test was used for testing differences on gender (nominal variable with two levels); Chi-square analysis was chosen for education and employment data (nominal variables with >2 levels); and the Mann-Whitney *U*-test for age and years of fishing experience (quantitative data).

For checking if significant differences on fishing behaviour existed across segments, the non-parametric tests used were: (i) Chi-square analysis followed by a Chi-square *post hoc* test, for testing if fishing persistency (i.e. number of fishers who still fish *vs.* those that stopped) varied across segments; (ii) Kruskal-Wallis H test followed by Dunn´s test for multiple comparisons (with Bonferroni corrections), to elucidate whether respondents' fishing behaviour (i.e. year of the first fishing event) differed between segments; and (iii) Mann-Whitney *U*-test to analyse whether perceptions on fish species changes were influenced by fishing experience (i.e. year of the first fishing event in the estuary).

The Spearman´s rank correlation was used to test: (i) the relation between changes in fish size and changes in number of active fishing licences; and (ii) the relation between the two ranking series (for each of the 20 social and environmental variables, fishers indicated their perception of (a) the general importance of the variable for fishing and (b) the current condition of the variable) (Spooren *et al.*, 2007; Murray, 2013).

For testing the level of correspondence between fisher´s perceptions and recorded data, two analyses were performed. Firstly, the Spearman´s rank correlation test was used to compare fishers´ perceptions of changes on five characteristics (i.e. abundance of catches, species variety of catches, catch size, water quality and number of recreational fishers) with changes on related recorded data (i.e. changes in demersal fish abundance, demersal fish richness, catches weight in annual fishing competition, oxygen saturation, ammonium concentration, and number of recreational fishing licences). To each of the respondents and for each of the five variables, a value of *recorded data change* was assigned. These values were estimated as the difference between the most recent value available (2015) and the value measured in the year when the respondent first fished in Nerbioi. When the respondent began to fish before any recorded data were available, the first available data were used (e.g. for a fisher that began to fish in 1985 in SEG1, the assigned value for fish abundance were the data of 1989, i.e. the first measurement available in SEG1). These *recorded data change* were calculated considering the segment where each respondent fished more days along the year.

To test if the level of correspondence between fisher´s perceptions of changes and *recorded data changes* was influenced by socio-economic characteristics and fishing experience, five logistic generalized linear models (GLM) were performed. The dependent variable was dichotomous (1: fishers´ perception matched the *recorded data change*; 0: there was no match) whereas the explanatory variables included quantitative variables (i.e., age, first fishing event at Nerbioi (year), years of general experience fishing) and nominal variables (i.e., sampling type (*in situ* or *ex situ*), gender, education level, frequency of fishing (general and at Nerbioi), type of fishing motivation (catch-oriented or other). To ensure that there was no multicollinearity among explanatory variables, the variance inflation factor (VIF) technique was used (Zuur *et al.*, 2010). If any explanatory variable had a VIF>3, the variable with the highest VIF value was removed sequentially, running the VIF analysis until all the variables had a VIF<3. To make a robust comparison between models, all the incomplete cases were deleted (e.g. fishers that answered NA (not appropriate) to the perceived change of a specific variable meant that it was not possible to assign a value to the dependent variable). For each of the five dependent variables, the model with the lowest Akaike Information Criterion value was selected, using the MuMIn package (Barton, 2016). If the selected model contained any explanatory variable with non-significant influence, a new model containing only that variable was run to check if the influence was significant. If the influence of the explanatory variable alone was not significant, the variable was definitively removed from the selected model. To check the reliability of the selected GLM´s against the null model (i.e. model built up without explanatory variables), a Likelihood Ratio Test (LRT) was carried out.

A significance level of $p<0.05$ was considered for all the tests performed.

3. Results

3.1. Assessment of the estuarine restoration

The water quality indicators improved from 1994 to 2015. Oxygen saturation at bottom waters significantly increased in segments SEG2-SEG5 (Figure B2(A)), while ammonium concentration at the surface significantly decreased in the outer Nerbioi and in the innermost segment (Figure B2(B)) (see also Appendix B Table 1).

The subsequent ecological improvement is shown by a clear spatial and temporal trend, from the outer to the inner estuary segments, with more fish species and more abundant fish over time. Indeed, a significant increase in fish richness in segments SEG2-SEG5 and a significant increase in fish abundance in the two innermost segments and in SEG2 was observed (Figure B2(C), B2(D) and Appendix B Table 1). Furthermore, the size of fish captured at the fishing competition in SEG3 also increased over time (Figure B3).

The number of active licences increased during the period 1999-2003, while from 2003 to 2004 decreased 14%. Afterwards, the number of licences increased again, reaching its maximum in 2011 (Figure B4). From then onwards, the number of active licences has decreased, with an accumulated reduction for the period 2011-2014 of 21%. The Spearman´s test showed statistically significant correlations between the size of the fish captured in the fishing competition in SEG3 (Figure B3) and the number of licences in the estuarine villages (Figure B4) (rho= 0.6265, p-value<0.01).

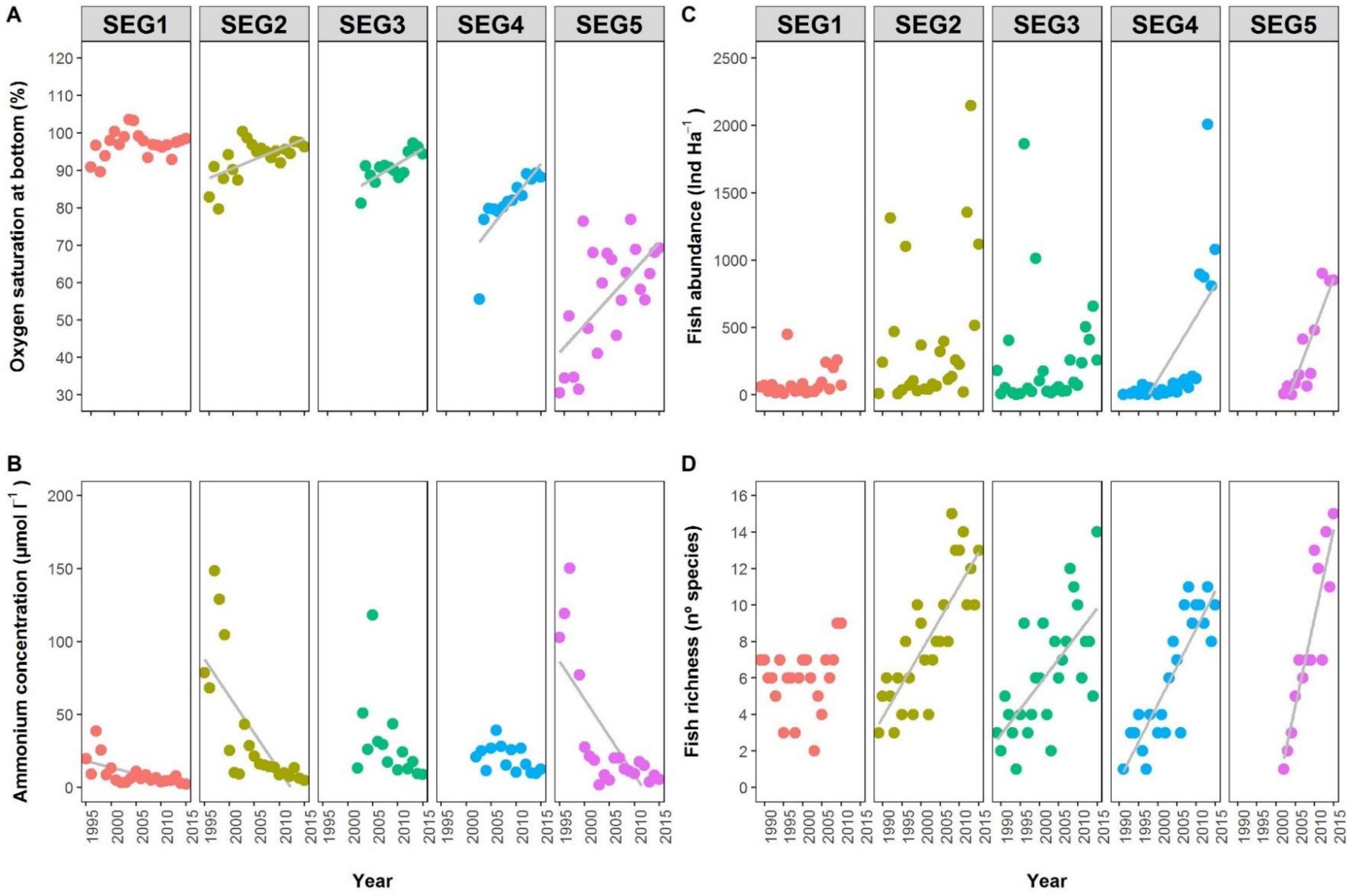


Figure B2 - *(A) Oxygen saturation at bottom and (B) Ammonium concentration at surface for the period 1994-2015. (C) Fish abundance and (D) Fish species richness trends for the period 1990-2015. Grey lines mean significant linear regressions (p<0.05).*

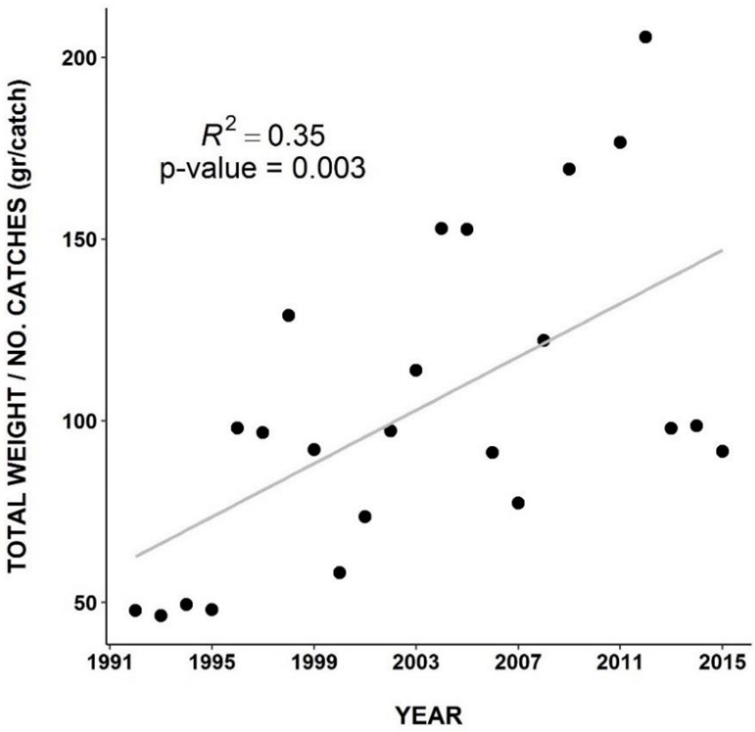


Figure B3 - *Trend in mean weight catches (weight of the total catches/total number of catches) in the annual fishing competition (grey line indicates linear regression).*

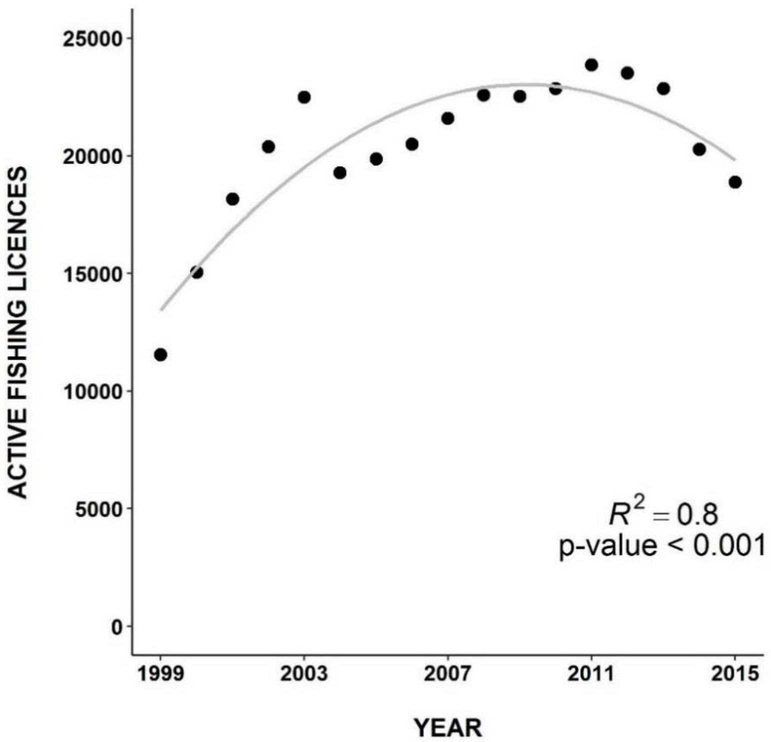


Figure B4 - *Trend in the number of active fishing licences (on-shore and spearfishing) in the villages located along the estuary (grey line indicates polynomic regression of grade 2).*

3.2. Recreational fishing in Nerbioi: characterization and changes over time

3.2.1. Fishers and fisheries characterization

A total of 146 completed questionnaires were obtained, 50 during *ex situ* sampling (50% response rate) and 96 during *in situ* sampling (95% response rate). From the total *in situ* questionnaires collected, 67 belonged to the outer Nerbioi and 29 to the inner Nerbioi (Appendix B Table 2). The highest number of anglers per sampling event was observed for the outer Nerbioi (Total anglers / samplings = 8.3 in SEG2 and 5.9 in SEG1) and the lowest for SEG4 and SEG5 (1.2 and 1.4, respectively). While the sampling success increased with a progression into the outer estuary, better coverage (i.e. completed questionnaires / total anglers) was made in two inner segments (>61% at SEG3 and SEG4 *versus* <47.5% in outer segments). In SEG5 only three questionnaires were obtained during the *in situ* samplings due to the few anglers present.

The profile of the average fisher in Nerbioi, as shown by the results of *in situ* and *ex situ* samplings, is a local (89% living in the villages along the estuary), middle-aged (51±14 years) man (93.2%) with long recreational fishing experience (29±16 years). In addition, they are mostly educated (49.3% with primary studies, 41.8% with secondary studies), but mostly inactive (17.2% unemployed and 34.2% retired). Only 6 out of 146 respondents (4%) did not hold an active fishing licence.

In the *ex situ* responses, there were significantly (i) more women answering the questionnaire (Fisher´s Exact test´s p=0.003), (ii) more respondents that had completed higher education (χ^2_3 =17.69, p< 0.001), and (iii) higher proportion of employed and self-employed people (χ^2_6=22.26, p<0.005). In turn, both *in situ* and *ex situ* sampled populations were statistically equal in terms of age (*in situ* Mdn=53 (n=96), and *ex situ* Mdn=52.5 (n=50), U=2319.5, p>0.05) and fishing experience (*in situ* Mdn=28 (n=96), and *ex situ* Mdn=30 (n=50), U =1951.5, p>0.05).

The three main drivers for fishing were relaxation (75.3%), to be with friends or relatives (41.1%), and to practice outdoor activities (31.5%), rather than reasons related with fish captures, which was only the motivation for <23%.

The most popular segment for fishing was SEG2, while the least frequented area was SEG5 (Table B1). Angling from shore was practiced in all the segments, while spear fishing and boat fishing are mainly practiced in the outer Nerbioi (Table B1). The highest change in fishing persistency corresponds to SEG1 and SEG4, where less than 72% continue fishing at present, followed by SEG5 (75%) and SEG3 (82.7%). In SEG2, the fishers were more constant than in the other four segments (>96% continue fishing today), and the difference with the other segments was significant (Chi-square p-value<0.05).

Table B1 - *Fishing in the Nerbioi estuary. Key: Ever fished: number of fishers who have ever fished; Fish now: number of fishers who currently fish; Fish now/Ever fished: number of fishers who fish at present divided by fishers who ever fished (value in percentage). The percentage values shown in brackets are calculated as: for fishing habits, from the total number of questionnaires (n=146); for fishing methods, from the total number of fishers who fish now in each segment. Different lettering (A,B) indicates significant differences in fishing habits between segments (p<0.05 after post hoc Chi-square test).*

	SEG1	**SEG2**	**SEG3**	**SEG4**	**SEG5**	**Statistical test**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	
Fishing habits	*A*	*B*	*A*	*A*	*A*	
Ever fished	103 (70.6)	112 (76.7)	75 (51.4)	35 (24)	12 (8.2)	
Fish now	74 (50.7)	108 (74)	62 (42.5)	25 (17.1)	9 (6.2)	Chi-square X^2: 26.58
Fish now/Ever fished (%)	71.8	96.4	82.7	71.4	75	
Fishing methods						
From shore	52 (70.3)	100 (92.6)	61 (98.4)	25 (100)	9 (100)	
Spear fishing	9 (12.2)	4 (3.7)	1 (1.6)	0	0	
From boat	22 (29.7)	5 (4.6)	0	0	0	
(No answer)	2 (2.7)	1 (0.9)	0	0	0	

A total of 32 different species were reported as being caught along the estuary (Appendix B Table 3), with only two species mentioned in all the segments: sea bass (*Dicentrarchus labrax*) and common sea bream (*Diplodus vulgaris*). These two species were the most frequently mentioned in segments SEG1-SEG4, ranking in first or second position. Horse mackerel (*Trachurus trachurus*), and cephalopods (*Loligo vulgaris, Sepia officinalis)* were frequently mentioned in the outer segments, but their importance decreased in the inner segments. In contrast, species such as red mullet (*Mullus* *surmuletus*) and sole (*Solea solea*) showed the opposite trend. The innermost segment showed a completely different species composition, with most frequent species (i.e. thicklip grey mullet (*Chelon labrosus*) and carp (*Cyprinus carpio*)) being representative of an oligohaline environment.

All 20 characteristics considered as potentially influencing the enjoyment of the fishing activity were important to fishers ($\bar{x}$=2.34-3.69, in a scale from 1=not important to 4=essential) and were perceived to be generally in good condition in the estuary ($\bar{x}$= 2.39-3.79 in a scale from 1=bad to 4=excellent) (Table B2). The characteristics with greater influence in the enjoyment were those related with water quality (i.e. absence of marine debris, foams and oils in the water and the absence of discharges nearby), while the characteristic with the lowest impact was “the absence of other fishers nearby”, followed by the “numerous catches”. The characteristics perceived in better conditions were “accessibility to fishing areas” and “proximity to home”.

There were statistically significant Spearman’s rank correlations between the importance and perceived condition of eight variables (Table B2). Seven of the significant correlations were positive (*rho*>0), and related to catches (i.e. number, size, diversity and food interest of catches), and water quality variables (i.e. absence of marine debris, oil and water odour). On the other hand, “accessibility to fishing spots” had a negative correlation between its importance and its perceived condition at Nerbioi (*rho<0,* p<0.05).

Table B2 - *Relation between importance and perceived condition of 20 characteristics within the Nerbioi estuary, expressed by Spearman´s rank correlations (significant p-values are highlighted in bold). Key: Mean score for importance from 1=not important to 4=essential; Mean values for perceived condition from 1=bad to 4=excellent; SD=standard deviation.*

	Importance for fishing enjoyment			**Perceived condition at Nerbioi**			**Spearman´s rank correlation**		
	n	**Mean score**	**SD**	**n**	**Mean score**	**SD**	**Paired n**	***rho***	**p-value**
General conditions									
Proximity to home	139	2.85	1.01	141	3.77	0.56	138	0.052	0.543
Accessibility	139	3.10	0.80	140	3.79	0.57	138	-0.245	**0.004**
Peace of the area / Tranquility	140	3.41	0.69	142	3.40	0.92	140	0.028	0.747
General cleanliness of the area	140	3.54	0.60	142	3.22	1.00	140	0.056	0.508
Water quality									
Water transparency	122	2.75	1.04	137	3.36	0.85	120	0.148	0.106
Absence of marine debris	140	3.57	0.54	141	2.78	1.10	139	0.243	**0.004**
Absence of foam in the water	137	3.5	0.65	142	3.23	0.97	137	0.130	0.130
Absence of oils in the water	138	3.69	0.46	140	3.13	1.02	137	0.220	**0.010**
Absence of water odour	137	3.65	0.58	141	3.38	0.97	136	0.187	**0.029**
Absence of residual discharges nearby	136	3.61	0.6	137	3.19	1.05	132	-0.023	0.796
Controls									
Fishing area delimited	129	2.50	1.07	111	3.02	1.14	106	0.123	0.209
Controls to fishers	137	3.02	1.00	125	2.50	1.21	123	-0.129	0.155
Controls of fishers´ catches	139	3.12	0.91	122	2.39	1.21	121	-0.161	0.078

	Importance for fishing enjoyment			**Perceived condition at Nerbioi**			**Spearman´s rank correlation**		
	n	**Mean score**	**SD**	**n**	**Mean score**	**SD**	**Paired n**	***rho***	**p-value**
Interactions									
Absence of numerous fishers	137	2.34	1.11	137	3.01	1.01	132	-0.073	0.409
Absence of boats	138	3.13	0.90	136	3.18	1.09	135	-0.022	0.799
Absence of people practicing aquatic sports	139	3.35	0.75	139	3.14	1.12	137	-0.062	0.469
Catches									
Numerous catches	139	2.48	1.07	139	2.44	1.10	137	0.219	**0.010**
Great size of catches	140	3.04	0.79	140	2.89	0.96	138	0.171	**0.046**
Great diversity of catches	140	2.85	0.90	138	2.99	0.96	136	0.195	**0.023**
Catches with food interest	138	3.24	0.76	137	3.58	0.73	136	0.330	**<0.001**

3.2.2. Changes of recreational fishing and fisheries over time

Anglers presented significantly different fishing patterns in different segments (Kruskal-Wallis test H_4=20.88, p<0.001), with fishers progressively entering to the inner segments over more recent years (Figure B5). The Dunn´s test confirmed a significant difference (p<0.05) between the outer Nerbioi and the two innermost segments (Figure B5).

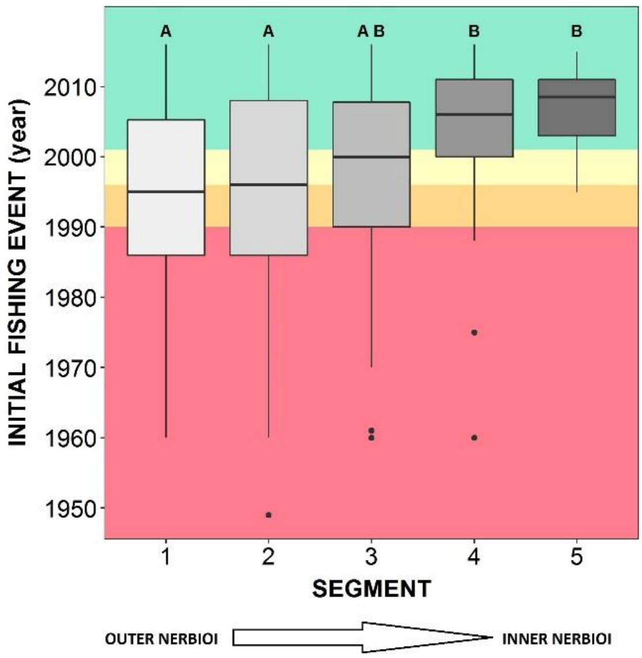


***Figure B5** - Median (Q_1:Q_3) year of first fishing event at the different segments of the Nerbioi. Background colours represent the main restoration phases in the estuary (from degraded: red, to near restored: green), following the milestones described in Section 2.1. Different lettering (A,B) indicates significant differences between segments (Dunn´s test p<0.05).*

From the 146 respondents, 50 answered that the most frequently captured species changed over time in the segments where they currently fish. Furthermore, a gradient was observed, as those who reported changes in species composition fished for the first time earlier than those who reported no changes. This difference was significant in segments SEG1:SEG2 (Table B3).

Table B3 *- Effect of Nerbioi fishing experience on the perception of changes in the most frequently fished species Key: Year 0 (mean): mean year of the first fishing event at Nerbioi; (^) Standard deviation cannot be estimated as there was a single answer. Significant p-values are highlighted in bold.*

	Species changed			**Species did not change**			**Mann-Whitney-U test**	
	n	**Year 0 (mean)**	**Stand Dev**	**n**	**Year 0 (mean)**	**Stand Dev**	***U***	**p-value**
SEG1	21	1986	11	52	1996	13	244.5	0.004
SEG2	27	1988	13	80	1997	14	642	0.003
SEG3	12	1992	14	50	2000	13	175	ns
SEG4	8	2003	8	16	2007	7	37	ns
SEG5	1	2000	^	8	2007	7		-

Only 38 respondents of those who reported a change in the most frequently caught species provided the names for the most frequent species in the past (1-5 species) (Appendix B Table 3). According to the respondents, *Diplodus vulgaris* and *Dicentrarchus labrax* were the most frequently caught species in the past; and these species were also mentioned as the most frequently caught species at present. Blackspot seabream (*Pagellus bogaraveo*) and pouting (*Trisopterus luscus*) were mentioned by few fishers as a frequent species in the past, but only one and none respectively, considered them as frequent at present (Appendix B Table 3).

Fishers´ perception of changes differed substantially among the five characteristics analysed. Fishers perceived mainly no changes in catches variety (36.3%) and size (45.2%). However, perceptions of changes in catch abundance and number of fishers were tilted towards deterioration, with more than 69% of respondents reporting a decrease in catch abundance and 78% reporting an increase in the number of fishers. In turn, a positive perception towards water quality improvement was mentioned by 80% of respondents; and 71% perceived that the implementation in Nerbioi of the WWTP led to better conditions for practicing recreational fishing.

Finally, no clear pattern was found in relation to whether the personal satisfaction with fishing has changed over time with 33% perceived no changes, 24% a deterioration and 29% an improvement. Despite this, from all the fishers who answered the questionnaire, 91% of them confirmed their intention to continue fishing at the estuary.

3.3. Do fishers´ perceptions match recorded changes?

The changes perceived by fishers did not match changes on recorded data, except for water quality perception ($p<0.05$ for the two water quality indicators) (Table B4). Although there is a significant correlation between perceived changes in catch size and recorded changes in the size of catches in the annual competition, this is a negative one, meaning that when a higher positive change is recorded for this characteristic, fishers perceived just the opposite situation.

Table B4 *- Spearman´s rank correlation test results for fisher´s perceived changes vs. recorded changes. Key: Recorded change is the difference between the most recent recorded value (2015) and the recorded value when each respondent first fished in Nerbioi (calculated with the data described in section 3.1.).*

Perceived change	**Recorded change**	**Spearman´s rank correlation**		
		N	***rho***	***p*-value**
Water quality	O_2 saturation (bottom)	99	0.227	**0.024**
	NH_4 (surface)	99	-0.293	**0.003**
Number of catches	Fish abundance	100	-0.091	0.370
Catch variety	Fish richness	101	-0.036	0.722
Catch size	Fish size	128	-0.303	**>0.001**
Number of fishers	Recreational fishing licences	134	0.073	0.401

The LRT was statistically significant in the five GLM´s (Table B5). There is a clear dominance of the variable "year of the first fishing event at Nerbioi", which appeared in four of the GLM´s. However, the sign of the coefficient for this variable differed among GLM´s: for changes in number of fishers (GLM5) and changes in water quality (GLM1), the sign matched the recorded data, i.e. perceptions of respondents with a longer fishing experience at Nerbioi were more in line with recorded changes than respondents who started fishing in the estuary more recently. In contrast, the perception of respondents with longer fishing experience were less in line with recorded data on changes in catch abundance (GLM2) and catch variety (GLM3) than that for less experienced fishers. In

GLM3, the variable sampling method was included, meaning that perceptions of fishers who answered the questionnaire *ex situ* were more in line with recorded changes than those from *in situ* respondents.

Table B5 - *Logistic GLM´s describing the effect of fishers´ profile in perceptions´ accuracy towards recorded changes. Key: (AICc) corrected Akaike Information Criterion, (LRT) Likelihood Ratio Test for the null model against the selected model. Significant correlations: *p<0.05; **p<0.01; ***p<0.001, and in bold for Z value.*

	Estimate	**Std. Error**	**Z value**	**Pr (>|z|)**	**AICc**	**LRT (χ^2)**
GLM1: Change on water quality (n=90)						
(Intercept)	276.42	55.54	4.97	**<0.001**	85.63	42.29***
First fishing event at Nerbioi (year)	-0.14	0.03	-4.97	**<0.001**		
GLM2: Change on number of catches (n=95)						
(Intercept)	-82.47	38.49	-2.14	**0.032**	109.22	5.00*
First fishing event at Nerbioi (year)	0.04	0.02	2.11	**0.035**		
GLM3: Change on catch variety (n=96)						
(Intercept)	-79.77	38.20	-2.09	**0.037**	114.52	16.04***
Sampling (=*ex situ)*	1.65	0.50	3.29	**0.001**		
First fishing event at Nerbioi (year)	0.04	0.02	2.06	**0.040**		
GLM4: Change on catches size (n=121)						
(Intercept)	-2.60	0.42	-6.15	**<0.001**	97.24	10.72**
Sampling (=*ex situ)*	1.72	0.54	3.16	**0.001**		
GLM5: Change on number of fishers (n=128)						
(Intercept)	210.03	40.77	5.15	**<0.001**	143.47	39.52***
First fishing event at Nerbioi (year)	-0.10	0.02	-5.15	**<0.001**		

Regarding the species composition, a 34% match was observed between the species present in the monitoring surveys and the species mentioned by the respondents; from the 32 species mentioned by fishers as being the most frequently caught species at present, 11 were present in the 2015 monitoring survey. However, the most frequent species in the monitoring surveys did not match with those listed by respondents as the most frequently fished. Indeed, the two most frequent species in the monitoring surveys (i.e. *Pomatoschistus* sp. and *Gobius niger*), present in all the years at least in one segment, are generally of negligible interest for recreational fisheries.

Conversely, the two most frequently caught species according to fishers (*Diplodus sargus* and *Dicentrarchus labrax*) ranked 6th and 24th, respectively, in the 'most abundant species-rank' for the whole environmental data series, and 16th and 24th in the abundance-rank for 2015.

4. Discussion

Understanding the connection between ecosystem restoration and provision of ecosystem services is important for scientists (Haines-Young and Potschin, 2010), and especially for managers (Ziv *et al.*, 2016). In recreational fishing, the selection of where and how to fish is influenced by social, economic and physical characteristics of fishers (Abernethy *et al.*, 2007), by environmental conditions, such as water quality (Hampton and Lackey, 1976), and by the presence of fish and the possibility of catching them (Fedler and Ditton, 1986; Arlinghaus, 2006).

This study suggests that in Nerbioi, the ecological changes registered in the last 25 years has resulted in an increase and extension of recreational fishing throughout the estuary. This is supported by (i) the water quality improvement, that allowed an increase in abundance and richness of fishes and enabled fish recolonization of the inner estuary; and (ii) the increase in the number of recreational fishing licences, which suggests a growing interest in the activity.

Fishers' behaviour can change in response to environmental changes (Fulford *et al.*, 2016). In the Nerbioi, recreational fishing activity has changed from being confined to the outermost part, to a gradual extension along the whole estuary, in accordance with the ecological improvement. This behavioural change matched the recovery milestones described by Borja *et al.* (2010a), suggesting an improvement in the delivery of ecosystem services and related recreational benefits within the estuary. The growing interest of recreational fishing in the Nerbioi, reflected in the extension of the activity to inner areas and the increase in the number of licences, could be linked to other changes not linked to the ecological recovery but to social changes, such as the increase in population. However, the population trend has been negative since 2009 in the villages located in the inner estuary, and since 2007 in the outer estuary (Eustat, 2017).

Despite the general improvement of the estuary, and the arrival of fishers into the inner parts of the estuary, differences in fishing pressure (i.e. concentration of anglers and variety of fishing methods) between estuarine segments indicates fishers´ preference for the outer Nerbioi. Indeed, the outer area holds the best water conditions and the highest marine fish richness of the estuary, with the innermost area holding species that are more typical from oligohaline environments. Interestingly though, in the outermost segment results suggest a decrease in the activity, probably due to the extension of port facilities in the past 20 years within that segment (Grifoll *et al.*, 2013), limiting the access to the shoreline. This change in the outermost segment is the unique remarkable change in infrastructure and/or shoreline access reported within the estuary since the beginning of the ecological recovery.

Fisher´s perceptions on changes in water quality support the idea of a correspondence between better environmental conditions and improvement of ecosystem services and benefits. Recreational fishing dependence on water ecological conditions has been reported elsewhere (Ribaudo and Piper, 1991; Vesterinen *et al.*, 2010), and although this has been questioned recently (Ziv *et al.*, 2016), this study shows that fishers changed their habits in response to water quality improvement. Furthermore, fishers rated some parameters related with water quality (e.g. absence of odour, oils and debris) as essential for enjoying fishing and perceived in good condition in the estuary. More experienced fishers are considered as having higher levels of knowledge (Thomas *et al.*, 2015) and indeed in this study those were the ones with the most accurate perception of water quality changes.

In turn, fishers´ perceptions on changes in catch abundance, variety and size, showed less clear patterns. Although catches are considered less important motivational factors than non-catch-related factors, in accordance with previous studies (Fedler and Ditton, 1994; Young *et al.*, 2016), catch abundance and size are known to affect fishing satisfaction (Arlinghaus, 2006; Griffiths *et al.*, 2017). In contrast, fisher´s perceptions towards the change in the conditions of these parameters after restoration were more negative than the changes shown by the recorded data (Borja *et al.*, 2016b); fishers perceived no improvements or deterioration in the three parameters. Also, the decreasing trends on certain species´ abundance suggested by fishers could not be confirmed by the data from the monitoring surveys. Previous studies already reported the mismatch that often exists between monitored environmental data and public perceptions (Danylchuk *et al.*, 2016). In this study, it has been hypothesized that the mismatch between fishers´ perceptions on catches parameters and recorded data could be explained by three reasons:

Firstly, the comparison was made using recorded data on demersal fish, while recreational fisher´s effort mainly focuses on pelagic species. Furthermore, the comparison between the most frequently caught species during monitoring surveys and the most frequently caught species according to fishers indicated a low correspondence between species of around one third. Also, species reported by fishers as currently being the most abundant do not correspond with the most abundant in monitoring surveys, and *vice versa*, with a low recreational interest of the most frequent species caught in those surveys. However, as an opposite argument, the recreational fishing competition, which targets the same species fished by the respondents, showed a positive trend in catch size, but fishers did not perceive such change.

Secondly, there is a general lack of connection between fishers' convictions and scientific information and knowledge on marine issues (Martin et al. 2016; Ressurreição et al. 2012). Also, this study found a dissonance between fishers´ perceptions (they reported a deterioration in catch parameters in the estuary) and their behaviour (they extended the fishing areas along the Nerbioi as they recovered over time). Such a difference between public perceptions and their behaviour or cognitive dissonance (Festinger, 1957), has also been reported in environmental studies (Thøgersen, 2004; Osbaldiston and Schott, 2012; Rubens *et al.*, 2015; Szostek *et al.*, 2017). At the same time, fisher´s profile characteristics (i.e. years of experience and frequency of fishing) have been found to affect fisher´s perceptions towards changes in the estuary; however, those characteristics influence fisher´s perceptions on catch changes in the opposite way to what it was predicted: respondents with longer fishing experience in the estuary and those who most frequently fish in the area, had a less accurate perception of changes of catch abundance and variety. Furthermore, Danylchuk *et al.* (2016) found that informal communication channels are important when it comes to sharing information regarding recreational fishing; however, the information in these channels might not be consistent with science-based information. Hence, recreational fishers might not be fully aware of ecological changes in the Nerbioi estuary, contributing to a distorted vision of the fishing conditions in the area and to the amplification of the dissonance between behaviour and perceptions.

The third reason that can explain the mismatch between recorded changes and fisher´s perceptions could be the increase in the number of recreational fishing licences issued in the last years, which can contribute to a higher fishing pressure and, consequently, to a lower number of catches per fisher. Indeed, respondents reported higher number of fishers in the estuary and, although there is a lack of correlation between the number of licences and the perception of changes in the number of fishers, these might be related with the short period of data available (last 16 years). Also, after a constant increase in the number of licences, a decrease has been registered in the last four years. The decrease can be associated with the perception of deteriorating catches, which might discourage fishers from continuing fishing in the area. Indeed, significant correlation was found between the trend in the number of licences and fish size, suggesting that the decrease in the size of fishes in the last years might discourage fishers from continuing fishing. Also, the decrease of licences in recent years could indicate that the area has reached its maximum carrying capacity in terms of recreational fishing, and the activity has started to degrade due to the high number of fishers. However, this argument contrasts with the perception of respondents on the number of fishers in the estuary; fishers deny that a high number of fishers in the fishing spots have a negative effect in their enjoyment of the activity. Therefore, it is improbable that a higher number of fishers is perceived as a factor affecting the number of catches at present and therefore discouraging fishers from continuing fishing there. It is of note that the importance placed on non-consumptive motivations by fishers in Nerbioi, and especially to a social motivation such as being with friends or relatives, which reinforces the idea of recreational fishing as a socio-cultural activity.

The positive effects of restoration reflected in both recorded data and fishers' behaviour contrast with the perceptions vs. recorded data mismatches and with the low change in fisher´s general satisfaction. Martin *et al.* (2016) mention how difficult is to positively influence the satisfaction of certain groups of recreational fishers, even when environmental conditions improve. The lack of positive change in fisher´s satisfaction could be related to the negative perception they reported on changes in catch abundance. Thus, although the number of catches have a low influence as a motivational factor for fishing in the Nerbioi, in accordance with previous studies (Fedler and Ditton, 1994; Arlinghaus and Mehner, 2004), they are a crucial element affecting how fishers value angling quality (Arlinghaus, 2005) and, therefore, might be affecting fishers´ general satisfaction.

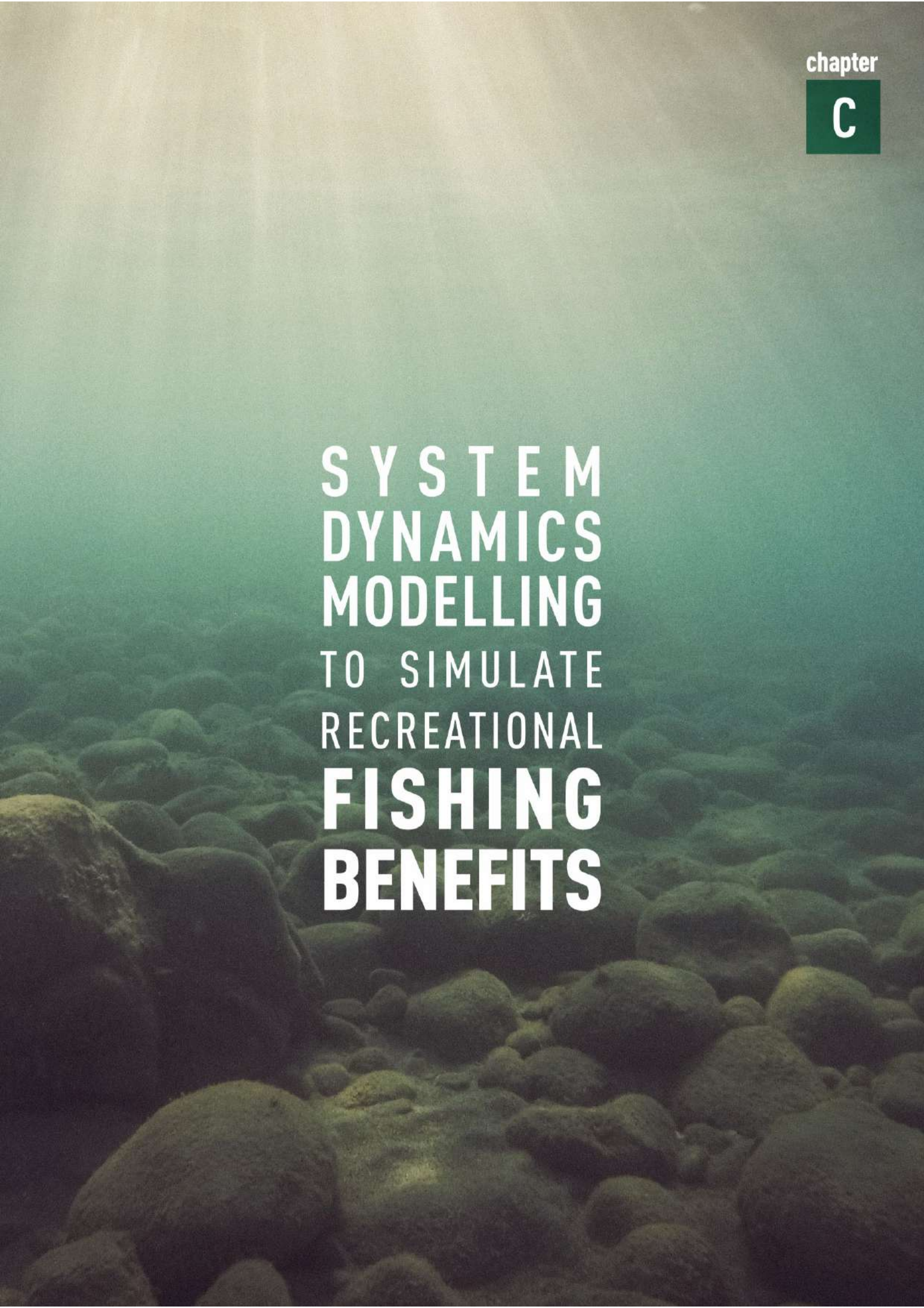
Even with the perception of fishers of having fewer successful fishing days in terms of number of catches, and with a lack of positive change in general satisfaction, they revealed their intention to continue fishing in the Nerbioi. Also, fishers rated the estuary as being in general good conditions for fishing. The Nerbioi estuary is an area that attracts fishers: it has high number of potential users who live nearby, a high number of easily accessible fishing spots, good water quality and appealing fish varieties. On the other hand, the difference in scores between the importance for enjoyment placed to control measures and their perceived condition in the Nerbioi, might be indicating little opposition towards an increase in recreational fishing controls. Cardona and Morales-Nin (2013) already reported fishers´ willingness of stronger controls in order to halt the catch depletion in the island of Mallorca, and contrary to other studies showing an opposition of recreational fishers towards controls (Arlinghaus, 2005; Thomas *et al.*, 2015). In the Nerbioi, fishers perceived a catch depletion that might be related to a loose legislation implementation and to scarce controls; therefore, fishers might show soft opposition to future control measures.

5. Conclusions

Despite the difficulties to fully comprehend fishers´ perceptions and behaviour, this study shows a clear link between environmental condition improvement (i.e. oxygen increase, ammonium decrease), ecological improvement (i.e. increase in fish abundance, richness and size) and increase in the provision of ecosystem services (i.e. increase of recreational fishing licences and movement of fishers to previously degraded areas). However, understanding – perceiving – behaving and satisfying does not always link in a linear manner, having many additional important factors (e.g. fishers´ profile, socio-cultural factors, ocean literacy, etc.). In the Nerbioi, the ecological recovery led to increased ecosystem services, but not to a full perception of benefits by users. In this context, more and better communication actions arise as a key point to effectively report the positive outputs of the restoration measures. Indeed, a crucial point in any successful restoration is that people perceive and value the environmental changes, as well as that they are satisfied with the benefits they received from a protected or recovered environment (Uyarra *et al.*, 2010).

The findings of this study support the idea of recreational fishing as a cultural ecosystem service that depends on a complex mixture of natural (e.g. water quality, fish population, etc.) and social factors (e.g. access to fishing spots or fishing gear) (Boyd and Banzhaf, 2007; Barbier *et al.*, 2011; Reyers *et al.*, 2013). The necessity of both factors for the development of the activity could explain why although factors related with catches are not generally perceive as improved, the interest of the Nerbioi estuary for fishing is still high. Indeed, when fishers´ satisfactions are used to measure ecosystem services, it is important to keep in mind that environmental factors such as water quality and catches characteristics are only part of the many factors that have an effect on fisher´s satisfaction (Sutton, 2007; Griffiths *et al.*, 2017).

A restoration project that results in an improvement in the ecological conditions could not be enough to achieve an improvement in the delivery of cultural ecosystem services and both ecological and social factors involved in the service production must be considered (Reyers *et al.*, 2013).



chapter

C

SYSTEM DYNAMICS MODELLING TO SIMULATE RECREATIONAL FISHING BENEFITS

Abstract

Recreational fishing activity has recovered in the Nerbioi estuary (Northern Spain), after water sanitation and environmental improvement. Recreational fishing is important for the local population; therefore, future management measures that could cause changes in the estuary should also consider the impacts on recreational fishing. The objective was to analyze the effects that future management decisions and unexpected environmental changes, alone or in combination with climate change effects, can produce in recreational fishing in Nerbioi. The current recreational fishing activity was modelled using a System Dynamics Modelling (SDM). Based on those results, seven future scenarios were simulated. Results suggest that the adoption of future management measures to improve the environmental conditions could lead to additional positive changes for recreational fishing, as after water quality improvement, fish stocks will continue to recover, and these better conditions could attract more fishers and increase their satisfaction. Simulation of temporary and unexpected environmental changes resulted in quick estuarine recovery, without dramatic consequences for recreational fishing. In conclusion, analysing future scenarios on cultural ecosystem services such as recreational fishing, using SDM, can produce valuable information for decision making processes, facilitating the selection between environmental management alternatives.

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1. Introduction

Estuaries play an essential role on human well-being (Bergstrom *et al.*, 2004). Multiple human activities, such as maritime transport, production and supply of natural resources and the practice of recreational activities, are developed and carried out in these environments (Costanza *et al.*, 1997; Wilson *et al.*, 2005; Barbier *et al.*, 2011).

Recreational fishing is one of the most common nature-based recreational activities performed in coastal areas worldwide (Arlinghaus *et al.*, 2012; Pita *et al.*, 2017). Being a relevant activity for human health and well-being, it is classified as a cultural ecosystem service (CES) (Abraham *et al.*, 2010; Hernández-Morcillo *et al.*, 2013) and a relevant social and economic activity, especially in industrialized countries (Arlinghaus *et al.*, 2016). Recreational fishing differs from commercial fishing in that "fishers do not sell the fish they catch", it "is not undertaken for predominantly subsistence purposes…", it is usually performed by catching fish on hooks, but "may include the use of small boats, the capture of fish by divers with spear guns and hand-gathering of shellfish from the beach or shore" (Pawson *et al.*, 2008).

When dealing with CES such as recreational fishing, the interactions between social end ecological factors should be analyzed (Reyers *et al.*, 2013). In this context, the social-ecological system framework has emerged as a useful approach to study marine ecosystem services (Outeiro *et al.*, 2017). Ecosystem services provide human benefits only after interacting with other forms of non-natural capital (i.e. human, social and built capital) (Costanza *et al.*, 2017). The social-ecological system approach considers these interactions between natural and non-natural elements and their outputs (Ostrom, 2007, 2009), which is useful in ecosystem services research. Indeed, recreational fishing is considered a complex social-ecological system (Arlinghaus *et al.*, 2017) and it has been analyzed accordingly (Hinkel *et al.*, 2014, 2015). For example, recreational fishers do not only look at environmental conditions when they decide to fish in an specific spot, but they usually consider other elements, such as social and infrastructure characteristics (Abernethy *et al.*, 2007; Griffiths *et al.*, 2017). However, the different dimensions of recreational fishing (e.g. human or social dimension and biological dimension) and the interactions between those dimensions are still not well understood (Fenichel *et al.*, 2013; Ward *et al.*, 2016), making the management of the activity a challenging task.

Effective management of recreational fishing needs an interdisciplinary approach that better captures the interactions between the different dimensions of the activity (Arlinghaus *et al.*, 2017). Managers and policy-makers should consider that environmental management decisions not only affect ecological aspects of the system but could affect the provision of ecosystem services, ultimately impacting related human benefits. Therefore, improving the ability to model the complexity of ecosystem services, by linking biophysical elements to social elements and reflecting what people really value, is critical for improving ecosystem management (Boyd *et al.*, 2016; Olander *et al.*, 2018) and for better policy design (Borja *et al.*, 2016a). Ultimately, integrating ecosystem services into environmental management requires the use of new measures or indicators able to capture not only the ecological changes, but also the social outcomes (Olander *et al.*, 2018).

System Dynamics Models (SDMs) represent one of the integrated environmental modelling approaches used to assist management decisions in social-ecological systems (Patterson *et al.*, 2004; Laniak *et al.*, 2013). SDMs provide a set of conceptual and quantitative methods useful to represent, explore and simulate feedbacks and non-linear interactions among system variables over time (Schmitt Olabisi *et al.*, 2010; Elsawah *et al.*, 2017). Furthermore, they are used to simulate the behavior of a system, to better understand its functioning and the cascading effects of any change in the system (Elsawah *et al.*, 2017).

Changes are clearly visible in the Nerbioi estuary, which during the 20th Century became severely degraded due to the industrialization, port and urban developments in the nearby villages and the direct discharge of non-treated industrial wastes and domestic sewage into its waters (Belzunce *et al.*, 2004a; Borja and Collins, 2004; Borja *et al.*, 2006).The implementation of the sewage treatment scheme, the adoption of environmental management measures and the industrial decline in the area (García-Barcina *et al.*, 2006) allowed the progressive ecological status recovery (Pascual *et al.*, 2012; Borja *et al.*, 2016b; Cajaraville *et al.*, 2016) as well as the recovery of CES such as recreational fishing, which is an important social activity for the local population

(Chapter B). This study aims at building a SDM that explicitly links the key socio-ecological elements that shape the recreational fishing activity in the Nerbioi, exploring how future environmental management decisions, unexpected changes and climate change effects could affect this activity. The final objective is to have a SDM useful for policy-makers and managers in taking science-based and cost-effective future management decisions, in social-ecological terms.

2. Methods

2.1. Study area

The Ibaizabal-Nerbioi and Kadagua are the two main tributaries and represent 93% of the freshwater inputs into the Nerbioi estuary (Uriarte *et al.*, 2014). Nowadays, the main water and contaminants inputs to the estuary come from the WWTP of Galindo and the two main tributaries.

As explained in Chapter B, recreational fishing in the Nerbioi is an activity practiced by locals, whose main motivations for fishing are not catch-oriented, but rather social. The most commonly used fishing method is shore-fishing, while boat fishing and spearfishing are less representative and restricted to the outer estuary. Catch-and-release is residual in the Nerbioi, as most fishes are kept for self-consumption.

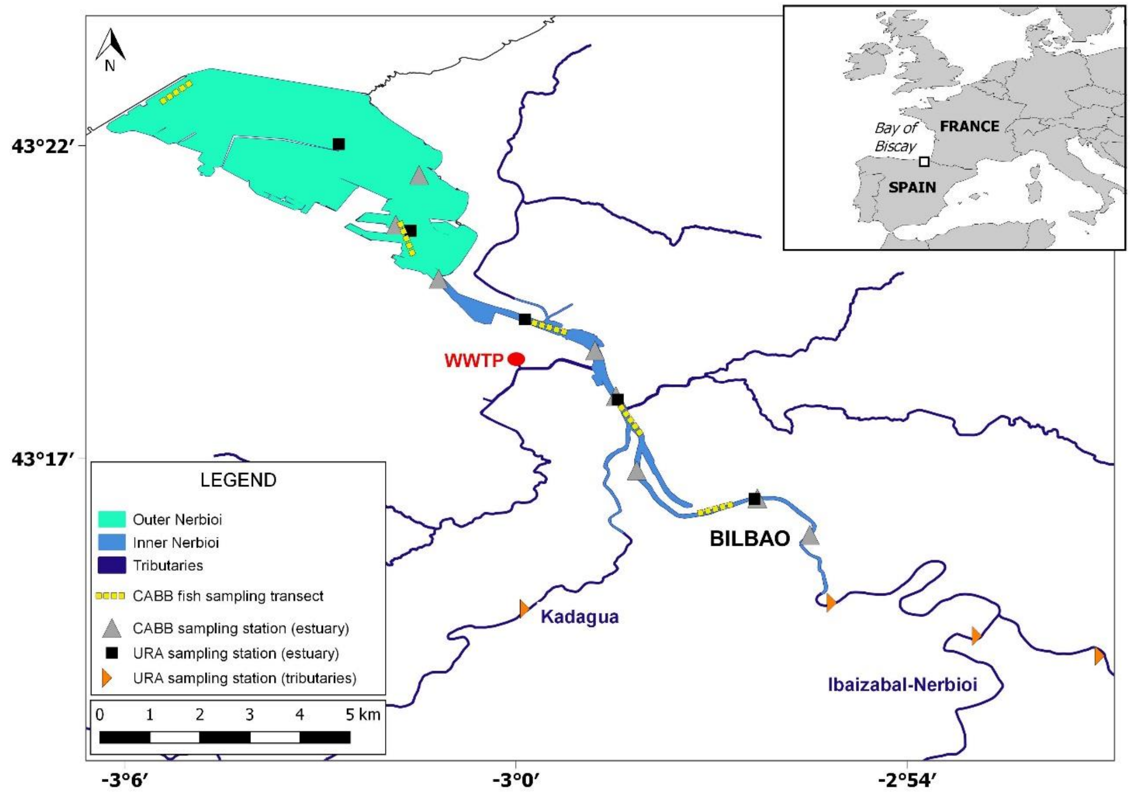

Figure C1 *- Location of the Nerbioi estuary within the Bay of Biscay, including the two main tributaries (Ibaizabal-Nerbioi and Kadagua) and the position of the Waste Water Treatment Plant (WWTP). Key: CABB: Bilbao-Bizkaia Water Consortium.*

2.2. Available data

Data used to build the SDM derived from the following five main sources:

- Bilbao-Bizkaia Water Consortium (CABB), which monitors biotic and abiotic parameters in the estuary since 1989 at eight sampling stations and five sampling transects (Figure C1). CABB also provided data on the annual mean loads of ammonium arriving to the estuary from the WWTP and tributaries.
- The Basque Water Agency (URA), which has also been monitoring biotic and abiotic parameters since 1994 at four sampling stations in the two main tributaries and at five sampling stations inside the estuary (Figure C1) (Borja *et al.*, 2016b).
- The regional on-shore fishing federation (FBPC), which organizes a fishing competition once a year since 1992, for which data on catches (number and weight) and number of participants are recorded.

- The Basque Government, which provides information on the number of recreational fishing licences issued for the period 1999-2015.
- Results of a questionnaire survey designed and distributed by the author among Nerbioi recreational fishers, between January-August 2016 (Chapter B).

URA and CABB collected similar data on biotic and abiotic parameters, but at different stations and with different frequency. As CABB has a longer time series and higher number of sampling stations, when data from the two sources were available, data from CABB were preferred (Appendix C Table 1).

2.3. System Dynamics Modelling and future scenarios

SDM allows the representation of non-linear and dynamically complex problems over time (Schmitt Olabisi *et al.*, 2010). This modelling tool was originally designed to represent industrial dynamics, although its use extended quickly to other areas such as socio-economic problems or social-ecological systems (Elsawah *et al.*, 2017). A SDM represents a problem as a network of cause-effect and feedback loops. There are mainly three types of elements in SDMs: stocks (i.e. state variables that represent accumulations), flows (i.e. changes in stocks over time) and auxiliary variables (i.e. any other variable such as constants). In this study, the SDM was built to represent the recreational fishing activity in the Nerbioi estuary. The model was written in VENSIM® DSS software language (version 5.6d) and designed to run from 2011 to 2030 with a time lapse of one month (0.0833 year). As recreational fishing is considered a complex social-ecological system (Arlinghaus *et al.*, 2016), dependent on ecological variables (e.g. fish stocks) and social variables (e.g. recreational fishers´ fishing skills) (Outeiro *et al.*, 2017), the SDM included both types of components and represented the feedbacks and non-linear interactions among variables over time. The ecological and social variables considered in the model and their interactions are further explained in section 3 of this chapter.

As projecting the future participation of people in the fishing activity is of considerable importance to a range of stakeholders, businesses and agencies (Arlinghaus *et al.*, 2015), the effects of environmental management measures were simulated to assess their potential impact on the recreational fishing activity. Future scenarios, based on plausible water management measures being already considered by local managers, unexpected environmental changes and climate change effects were simulated, without entering into the exploration of recreational fishing management measures. To check if significant differences exist between the baseline and future scenarios, Friedman rank sum test was used. Friedman rank sum test is similar to the parametric ANOVA for repeated measures, and it has been typically applied to detect differences between treatments (Pereira *et al.*, 2015). When the result indicated a significant difference, the Nemenyi *post hoc* test was conducted to compare the scenarios by pairs (Hollander *et al.*, 2014), using the PMCMR package (Pohlert, 2014) in R environment (R Core Team, 2017).

3. The System Dynamics Model

The SDM was designed using two interconnected sub-models: the ecological and the social sub-models (Figure C2). The social-ecological conditions in the estuary in 2011 were considered as the baseline of the model (time=0), and at the beginning, all the variables were fixed to show a stable situation (from now onwards, baseline scenario).

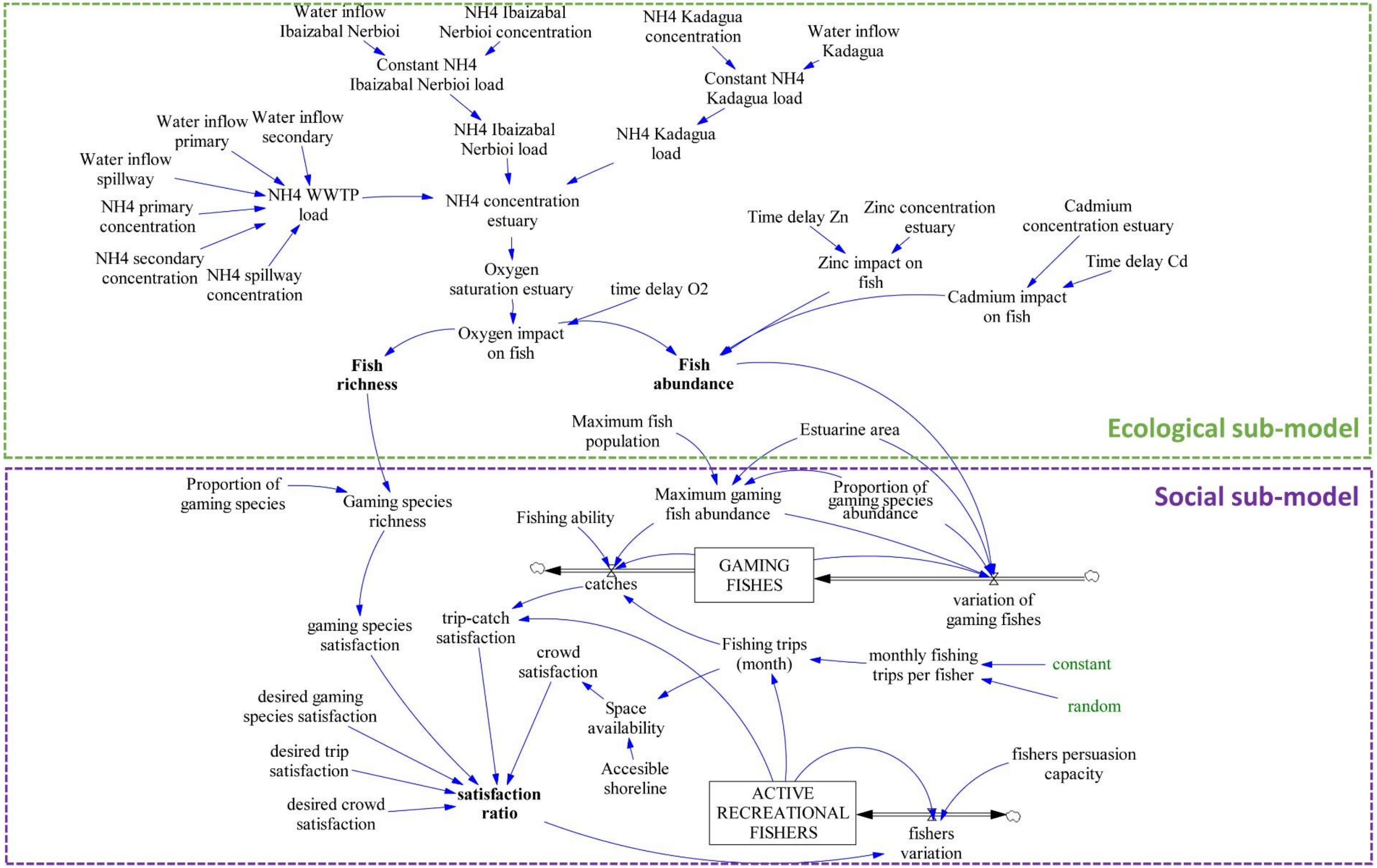

Figure C2 - *System Dynamic Model for recreational fishing at Nerbioi estuary, divided into two sub-models for better comprehension.*

3.1. Ecological sub-model

The ecological sub-model represents the ecosystem components that support the recreational fishing at the Nerbioi. Fish abundance and richness were chosen as the outputs of the sub-model, due to their importance for recreational fishing (Fedler and Ditton, 1986; Arlinghaus, 2006). Physicochemical and biological variables measured in the estuary and presenting significant relationships with fish abundance and richness (Appendix C Table 2), completed the sub-model. The protocol for the selection of variables as well as the relations between them are briefly explained below (see also Appendix C Protocol and Appendix C Table 2). For the statistical analysis undertook to determine the equations relating these variables, a significance level of $p<0.05$ was considered.

Previous studies in Basque estuaries indicated that oxygen saturation and ammonium concentration are adequate predictors of fish abundance and richness (Uriarte and Borja, 2009). The potential effect of other abiotic and biotic variables in fish abundance and richness was also explored. Since oxygen is one of the main limiting factors for marine biota, and 80% of oxygen saturation considered the threshold between moderate and good ecological status (Uriarte and Borja, 2009), the statistical analysis was performed in two steps: first, all samples were analysed together; and second, data were split in two groups: samples with oxygen saturation <80% and samples with >80% oxygen saturation. After the analysis, oxygen saturation was found to be the most significant variable affecting fish richness (at any oxygen saturation) and fish abundance (when oxygen saturation <80%). In samples where oxygen saturation >80%, Cd and Zn had significant negative effects on fish abundance.

An unexpected and temporary negative impact on a system could cause dramatic changes in biological elements, such as fish, which will need a variable time to recover after removing the pressure (Borja *et al.*, 2010a). To simulate this time span between pressure removal and biological recovery, the equations that linked oxygen saturation, Cd and Zn concentrations with fish abundance and richness included a delay, that smoothed the curve of the equation.

Oxygen saturation was negatively correlated with ammonium concentration in the estuary. Likewise, ammonium concentration in the estuary was positively correlated with the three main ammonium loads (WWTP and the two river tributaries) that were used as inputs of the sub-model. Nowadays, the ammonium load arriving from the WWTP to the estuary is composed by three different spills (spillway, primary and secondary), with a variable ammonium concentration. For Cd and Zn, the concentrations measured in the estuary were used as direct inputs of the ecological sub-model, as no significant relations could be found between the concentrations in the estuary and concentrations in tributaries.

3.2. Social sub-model

The social sub-model represents the recreational fishing as a human benefit, and links the ecosystem components (i.e. ecological sub-model) to the human and social capital (as defined by Costanza *et al.* (2017)). Recreational fishers´ satisfaction is considered a way to measure anglers´ well-being (Ward *et al.*, 2016) and catches are considered of importance when determining overall fishing satisfaction (Arlinghaus, 2006). But recreational fishing has other social components (e.g. social interactions between fishers) that can affect overall satisfaction (Arlinghaus, 2006; Chapter B). The sub-model variables and their relationships are described in Appendix C Table 2.

The first two inputs for the social sub-model are fish richness and fish abundance, which were the outputs of the ecological sub-model. The gaming species abundance and richness were estimated using total values of fish abundance and richness in the estuary and considering that 34% of the total number of fish species present in the estuary were reported by recreational fishers as gaming species (Chapter B).

Apart from the two inputs flowing from the ecological sub-model, the social sub-model was fed by seven additional inputs, related with space availability and fishers´ characteristics. The first two of those seven inputs are estuarine area and maximum fish population that together with fish abundance and proportion of gaming fish abundance were used to estimate how many gaming fishes “enter” the estuary (i.e. positively affected the gaming fishes).

Catches were defined as a flow variable that negatively affects gaming fishes and four inputs were used to estimate them: maximum fish population, fishing ability, number of active recreational fishers and the mean monthly visits per fisher. Fishing ability was calculated with data gathered by the FBPC at the annual fishing competition.

The number of active recreational fishers in the Nerbioi estuary was estimated at 2,500 fishers, using the results of the questionnaires used by Ruiz *et al.* (2014) and in this thesis (Chapter B). Fishers are estimated to do 2.5 fishing trips per month to the estuary (i.e. monthly fishing trips per fisher); altogether, the estuary receives 6,250 monthly fishing trips.

The last input to the sub-model is the accessible shoreline, used to estimate the space availability (i.e. the number of metres available for each fisher at each fishing trip).

Overall recreational fishing satisfaction (i.e. satisfaction ratio, scale 0-1) was considered as being dependent on three satisfactions that contribute in a different proportion to the overall satisfaction ratio: gaming species satisfaction (weight=0.2), trip-catch satisfaction (weight=0.5) and crowd satisfaction (weight=0.3). The trip-catch satisfaction contributed the most to the overall satisfaction (Arlinghaus, 2006; Griffiths *et al.*, 2017). These three types of satisfaction were defined in a 0-3 scale (0 =not-satisfied, 3 =maximum satisfaction) and based on the results from Chapter B. For fishing species satisfaction, and as current gaming species richness is valued in "good" status by recreational fishers (current value =2 in a 0-3 scale), and considering current gaming species richness is ~8, the minimum satisfaction was considered when gaming species richness=0 and the maximum satisfaction when ≥10. Trip-catch satisfaction was considered as being dependent on the number of catches per fisher. Current monthly catches were estimated at 2.06 catches/fisher and therefore, valued as in "average-poor" status (current value =1.06 in a 0-3 scale). Minimum satisfaction was considered when catches =0, and maximum satisfaction when catches ≥4. Finally, crowd satisfaction was defined as a function of space availability. Current space availability is equal to 40 lineal meters and considered as being in "good" status (current value =2 in a 0-3 scale); therefore, minimum satisfaction was considered when space availability =0 meters and maximum satisfaction when space availability is between 60 and 80 metres. At higher space availabilities, satisfaction is considered to decrease (until ≥200 metres, where satisfaction =1), as high space availability represents a situation with limited options for social interaction, which is of high importance (Chapter B).

Fisher persuasion capacity was used to estimate how many fishers quit fishing or how many new fishers will start fishing in the estuary. When satisfaction ratio >0.55, fishers are mainly meeting their expectations and therefore convince new fishers to come to the Nerbioi (fishers persuasion capacity=1 and fishers' variation is positive). When satisfaction ratio <0.45, fishers are not meeting their expectations, and some quit fishing (fishers persuasion capacity = - 0.1 and fishers' variation is negative). When satisfaction ratio is between 0.45 and 0.55, a stable situation where variation in the number of fishers equals zero was considered.

4. Future scenarios

The SDM was adapted to simulate different future scenarios, changing the existing equations or adding new variables (Figure C3). In all the scenarios, the changes introduced were set to start in 2020 and run until 2030.

A total of eight simulations were run: the baseline scenario, with stable social-ecological conditions (see section 3) and seven future change-scenarios. The main characteristics and results of the eight simulations are summarized in Table C1.

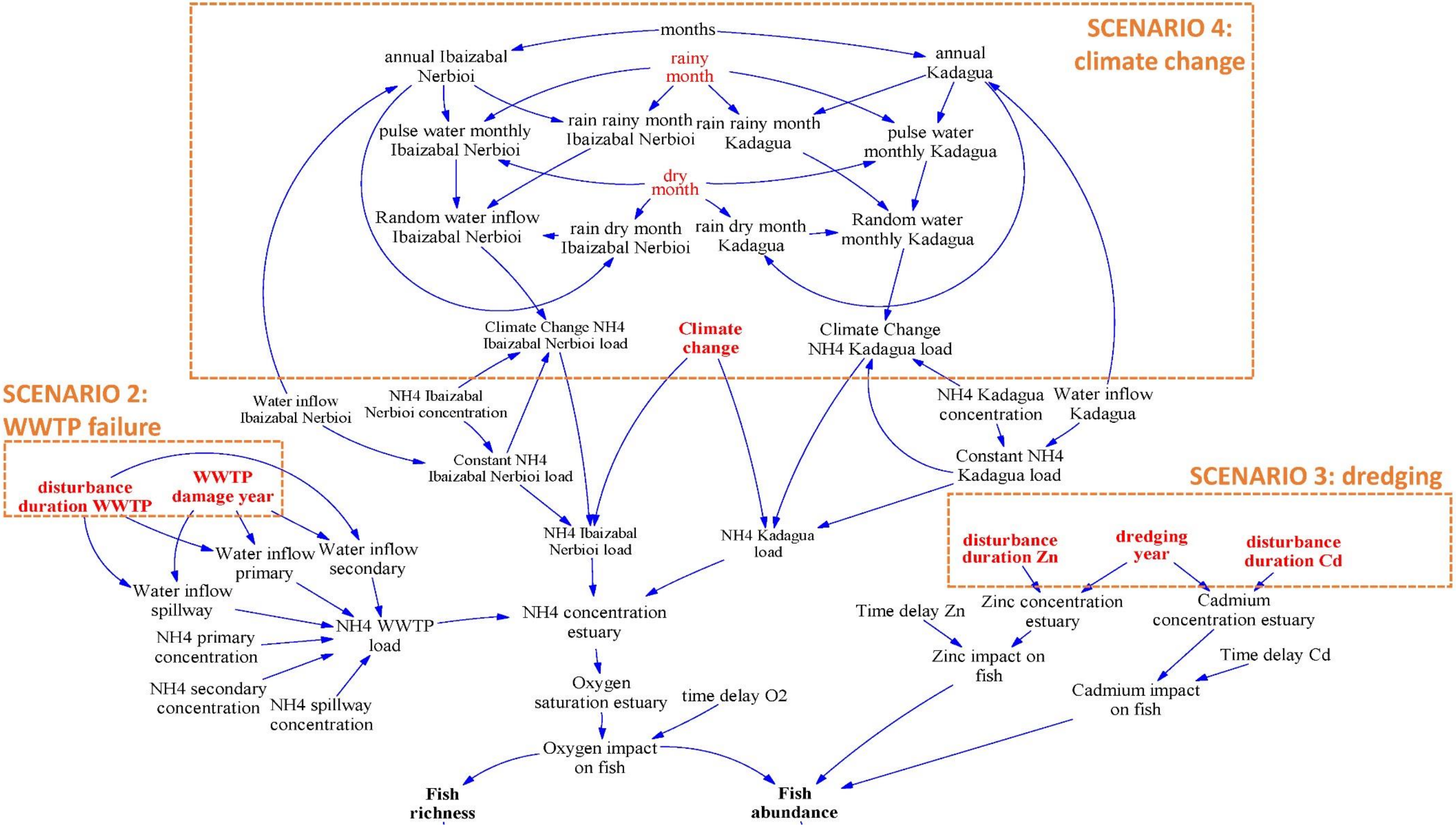

Figure C3 - *Sketch of the ecological sub-model, with the variables added to simulate SC2,3 and 4.*

Table C1 *- Changes experienced by the socio-ecological system under the seven future-change-scenarios tested in the System Dynamics Model, compared with the baseline scenario. The change between the simulated scenario and the baseline is expressed as percentage (values in parentheses). Empty cells indicate no change, compared with the baseline. Key: N: number; Ind: Individuals. Simulation moment 0.0833=1 month.*

Scenario	**Disturbance**			**Simulation moment (year)**	**Loads**			**Ecological sub-model**						
	Description	**Year**	**Duration**		**WWTP**	**Ibaizabal-Nerbioi**	**Kadagua**	**NH4**	**O2**	**Zn**	**Cd**	**Fish richness**	**Fish abundance**	**Gaming fishes**
					million mol month^{-1}	*million mol month^{-1}*	*million mol month^{-1}*	*µmol l^{-1}*	*%*	*µg l^{-1}*	*µg l^{-1}*	*N species*	*Ind Ha^{-1}*	*million Ind*
Baseline	Steady situation				1.65	0.51	0.20	21.37	91.6	15.95	0.16	20	274	1.07
SC1	Construction of the submarine outfall	2020	Permanent	2022	0 (-100.0)			12.69 (-40.6)	101.6 (10.9)			25 (30.3)	563 (105.6)	1.08 (0.5)
				2030	0 (-100.0)			12.69 (-40.6)	107.1 (16.9)			29 (50.8)	839 (206.3)	1.09 (1.9)
SC2	Failure in the WWTP	2020	2 months	2020.1	19.51 (1,082.4)			115.41 (440.1)	84.6 (-7.7)			16 (-17.0)	165 (-39.8)	
				2030					91.5 (-0.1)			19 (-0.3)	272 (-0.7)	1.07 (-0.2)
SC3	Dredging	2020	4 months	2020.2						22.93 (43.8)	0.23 (43.7)		193 (-29.7)	
				2030										
SC4	Redistribution of rain pattern	2020	Permanent	2022.1		2.46 (380.0)	1.05 (380.0)	62.36 (191.8)	93.7 (2.3)			21 (5.7)	319 (16.4)	
				2030		0.12 (-76.0)	0.05 (-76.0)	13.18 (-38.3)	94.05 (2.6)			21 (6.6)	326 (19.1)	
SC5	SC1+SC4	2020	Permanent	2022.1	0 (-100.0)	2.46 (380.0)	1.05 (380.0)	53.67 (151.1)	104.0 (13.4)			27 (38.6)	667 (143.4)	1.07 (0.4)
				2030	0 (-100.0)	0.12 (-76.0)	0.05 (-76.0)	4.492 (-79.0)	110.0 (19.6)			31 (60.8)	999 (264.8)	1.09 (1.9)
SC6	SC2+SC4	2020	Permanent +2 months	2020.1	19.51 (1,082.4)	2.46 (380.0)	1.05 (380.0)	156.4 (631.9)	85.2 (-7.0)			16 (-15.7)	172 (-37.1)	
				2030		0.12 (-76.0)	0.05 (-76.0)	13.18 (-38.3)	94.0 (2.5)			21 (6.4)	324 (18.3)	1.07 (-0.3)
SC7	SC3+SC4	2020	Permanent +2 months	2020.2		2.46 (380.0)	1.05 (380.0)	62.36 (191.8)	89.2 (-2.7)	22.93 (43.8)	0.23 (43.7)	18 (-6.4)	161 (-41.2)	
				2030		0.12 (-76.0)	0.05 (-76.0)	13.18 (-38.3)	94.1 (2.6)			21 (6.6)	326 (19.1)	1.70 (58.9)

Scenario	**Disturbance**			**Simulation moment (year)**	**Social sub-model**					
	Description	**Year**	**Duration**		**Active fishers**	**Catches**	**Gaming sp. satisfaction**	**Trip-catch satisfaction**	**Crowd satisfaction**	**Overall satisfaction**
					N fishers	*Ind month*$^{-1}$	*0-3 scale*	*0-3 scale*	*0-3 scale*	*0-1 scale*
Baseline	Steady situation				2,500	5,148	1.90	1.06	2.00	0.50
SC1	Construction of the submarine outfall	2020	Permanent	2022	2,860 (14.4)	5,915 (14.9)	2.95 (55.3)	1.07 (0.8)	1.76 (-12.2)	0.55 (9.4)
				2030	3,128 (25.1)	6,559 (27.4)	3.00 (58.0)	1.10 (3.5)	1.60 (-19.9)	0.54 (7.9)
SC2	Failure in the WWTP	2020	2 months	2020.1			1.58 (-17.0)			0.48 (-4.3)
				2030		5,135 (-0.3)	1.89 (-0.3)	1.05 (-0.5)		0.50 (-0.3)
SC3	Dredging	2020	4 months	2020.2				1.06 (-0.1)		
				2030						
SC4	Redistributio n of rain pattern	2020	Permanent	2022.1		5,145 (-0.1)	2.02 (6.2)	1.06 (-0.1)		0.51 (1.5)
				2030			2.05 (8.0)			0.51 (2.0)
SC5	SC1+SC4	2020	Permanent	2022.1	2993 (19.7)	6,185 (20.1)	3.00 (58.0)	1.07 (0.7)	1.68 (-16.2)	0.55 (8.4)
				2030	3130 (25.2)	6,563 (27.5)	3.00 (58.0)	1.10 (3.5)	1.60 (-20.0)	0.54 (7.9)
SC6	SC2+SC4	2020	Permanent +2 months	2020.1			1.60 (-15.6)			0.48 (-3.9)
				2030		5,134 (-0.3)	2.04 (7.4)	1.05 (-0.6)		0.51 (1.7)
SC7	SC3+SC4	2020	Permanent +2 months	2020.2			1.78 (-6.4)			0.50 (-1.6)
				2030			2.05 (8.0)	1.06 (-0.1)		0.51 (2.0)

In the first future scenario (SC1), there were evaluated the consequences of the project that the local government and the water management authorities have announced in recent years: the construction of a coastal submarine outfall to divert the current WWTP discharges. This situation was simulated turning the NH_4 concentration of the three WWTP spills to 0 in 2020. This scenario resulted in 40% decrease of ammonium concentration and 17% increase in oxygen saturation. Fish abundance and richness also increased, causing an increase in catches (14.4% in 2022 and 27.4% in 2030). Overall satisfaction will increase 8% by 2030, although crowd satisfaction would decrease (20%) due to the increase in the number of active fishers (25%).

In SC2 a hypothetical failure of the WWTP for two months at the beginning of 2020 was simulated. It was assumed that the total volume of water arriving to the WWTP would be discharged with no treatment into the estuary. The failure resulted in an immediate increase in NH_4 concentration (440%) and a decrease in oxygen saturation (8%). The ammonium and oxygen parameters recovered quickly once the pressure disappeared, but fish abundance and richness, which decreased 40% and 17% respectively, needed until 2030 to recover. The number of active recreational fishers did not vary but overall satisfaction decreased 4.3% right after the impact, almost recovering the initial value by 2030.

In SC3, it was hypothesized on the effects of dredging works. Dredging in the estuary is a common practice to ensure navigability; this can resuspend sediments, including metals (Belzunce *et al.*, 2001). A single dredging event that will resuspend the sediments and increase the concentration of Cd and Zn 50% was simulated in 2020. After dredging, changes in the concentration of metals in waters are likely to have a short-term effect (Ohimain *et al.*, 2008); so it was considered that the increase in metals concentration will be dissipated in four months. This scenario caused an immediate decrease in fish abundance (30%), but the effect disappeared after two years. This temporary decrease did not translate to negative effects in the social sub-model, as no changes were registered in catches, number of active recreational fishers or satisfaction.

In SC4, it was simulated the effects of the change in the annual precipitation pattern due to climate change. The climate in the Basque Country could shift to a more Mediterranean climate, with an increase in the number of dry days and the accumulation of precipitation in shorter time (Monjo *et al.*, 2014). It was considered that 80% of the annual water arriving from the tributaries to the estuary will be accumulated in 2 months, and the remaining 20% in 10 months. This simulation caused short periods of increase on ammonia concentration with longer periods of decrease in the same variable. Consequently, fish abundance and fish richness oscillated, which ultimately derived in an oscillation on the overall satisfaction. However, the number of active recreational fishers did not vary.

Finally, three additional scenarios were created as the combination of climate change effects with the construction of the marine outfall (SC5), the failure of the WWTP (SC6) and dredging (SC7). The SC5 resulted in similar changes to the ones obtained in SC1, but with more oscillation caused by climate change (Appendix C Figure 1). The instability simulated in precipitation pattern caused oscillations in ecological variables such as fish richness and fish abundance, but the results in the social sub-system (e.g. catches, overall satisfaction and number of active recreational fishers) followed the positive trend observed in SC1. In SC6, negative impacts on fish abundance and fish richness (-37.1% and -15.7%, respectively) were reported right after the WWTP failure (Appendix C Figure 2). After the effect of the failure disappeared, the trends and values of the variables in 2030 were similar to SC4. Finally, in SC7 a 41% decrease in fish abundance was registered right after the disturbance. Once the effects of dredging dissipated, the variables followed the pattern already observed in SC4: ammonium concentration, fish abundance and fish richness oscillations, that consequently affected the overall satisfaction (which by 2030 increased a 2%) (Appendix C Figure 3). Catches and number of active recreational fishers remained constant.

The statistical analysis was run with simulation data for 2020-2030 and in four variables: fish abundance, fish richness, number of fishers and overall satisfaction data. When comparing the baseline scenario with the future scenarios, it was seen that the construction of the submarine outfall (SC1 and SC5) can cause significant changes in the four variables analyzed (Friedman test p-value<0.001, for the four comparisons) (Table C2). There were significant differences between the baseline scenario and the two WWTP failure scenarios (SC2 and SC6) on fish variables and overall satisfaction (Friedman test p-value<0.001), while dredging works scenarios (SC3 and SC7) caused significant changes on fish abundance and overall satisfaction (Friedman test p-value<0.001). When comparing the future scenarios with their equivalent exposed to climate change, it was seen that in the coastal submarine outfall scenarios the paired comparisons were significant for the number of active fishers and overall satisfaction (*post hoc* test <0.05). In the WWTP failure scenarios differences were only significant for the overall satisfaction (*post hoc* test p<0.001), while in the dredging works scenarios, none of the paired comparisons were significant (*post hoc* test p>0.05). Although the statistical analysis revealed significant differences for some parameters across scenarios, over time, the general patterns observed for the four analysed variables are similar (Appendix C Figures 1, 2 and 3), meaning that for those scenarios were there was a certain trend (increase or decrease) without climate change, when climate change effects were added, the trend was the same.

Table C2 - *Paired comparison of the baseline scenario (BS) with the different future scenarios (SC), with or without climate change effects, on four variables (i.e. fish richness, fish abundance, number of active fishers and overall satisfaction). Analysis performed using Friedman rank sum and Nemenyi post hoc tests. Key: p-values in bold indicate significant differences (p-value<0.05).*

	Friedman test Chi-square		**Nemenyi *post hoc* test**		
	X^2	**p-value**	**Comparison**	X^2	**p-value**
Fish richness					
Marine outfall (BS, SC1 & SC5)	169.87	**<0.001**	BS-SC1	12.16	**<0.001**
			BS-SC5	10.84	**<0.001**
			SC1-SC5	1.32	0.62
WWTP failure (BS, SC2 & SC6)	104.22	**<0.001**	BS-SC2	9.45	**<0.001**
			BS-SC6	8.59	**<0.001**
			SC2-SC6	0.86	0.82
Dredge (BS, SC3 & SC7)	4.267	0.118			
Fish abundance					
Marine outfall (BS, SC1 & SC5)	169.87	<0.001	BS-SC1	12.16	**<0.001**
			BS-SC5	10.84	**<0.001**
			SC1-SC5	1.32	0.62
WWTP failure (BS, SC2 & SC6)	169.87	<0.001	BS-SC2	9.45	**<0.001**
			BS-SC6	8.59	**<0.001**
			SC2-SC6	0.86	0.82
Dredge (Baseline, SC3 & SC7)	18.874	<0.001	BS-SC3	3.57	**0.031**
			BS-SC7	3.57	**0.031**
			SC3-SC7	0	1
Number of active fishers					
Marine outfall (BS, SC1 & SC5)	199.39	**<0.001**	BS-SC1	7.47	**<0.001**
			BS-SC5	13.65	**<0.001**
			SC1-SC5	6.18	**<0.001**
WWTP failure (BS, SC2 & SC6)	*No change*				
Dredge (BS, SC3 & SC7)	*No change*				
Overall satisfaction					
Marine outfall (BS, SC1 & SC5)	211.25	**<0.001**	BS-SC1	14.87	**<0.001**
			BS-SC5	7.93	**<0.001**
			SC1-SC5	6.94	**<0.001**
WWTP failure (BS, SC2 & SC6)	201.6	**<0.001**	BS-SC2	9.52	**<0.001**
			BS-SC6	4.76	**0.002**
			SC2-SC6	14.27	**<0.001**
Dredge (BS, SC3 & SC7)	66.142	**<0.001**	BS-SC3	7.99	**<0.001**
			BS-SC7	5.98	**<0.001**
			SC3-SC7	2.02	0.33

5. Discussion

Recreational fishing is a complex social-ecological system (Arlinghaus *et al.*, 2017), influenced by social, economic and physical characteristics of fishers (Abernethy *et al.*, 2007), by the available infrastructure around fishing sites, such as piers or access points (Griffiths *et al.*, 2017), by environmental conditions, such as water quality (Hampton and Lackey, 1976) and by the presence of fish and the possibility of catching them (Fedler and Ditton, 1986; Arlinghaus, 2006). Increasing the understanding of all these elements and the links between them is crucial for improving the management of these social-ecological systems (Ziv *et al.*, 2016; Outeiro *et al.*, 2017).

Consequently, when valuing recreational fishing as a CES, it is insufficient to consider only the ecological conditions as indicators of the ecosystem service (Ziv *et al.*, 2016), as both environmental and sociocultural factors influence the activity (Reyers *et al.*, 2013) and, ultimately, the service users' benefits.

In this study, the available information of social-ecological components that shape the recreational fishing activity (Fenichel *et al.*, 2013) at the Nerbioi estuary were used to design a SDM that could measure the consequences of future environmental changes and management decisions on this ecosystem service.

Environmental restoration can have a remarkable positive effect in ecosystem services and human well-being (Elliott *et al.*, 2007). In the Nerbioi estuary, restoration produced a recovery in the biological value (Pascual *et al.*, 2012), allowing the increase and extension of recreational fishing (Chapter B). Therefore, if new management measures are being planned, effects on recreational fishing and consequently, in human benefits should now be considered.

Recreational fishing is classified as a CES (i.e. non-material benefits that humans obtain from nature), and therefore, defining appropriate indicators for measuring it is complex (Hernández-Morcillo *et al.*, 2013). When working with recreational ecosystem services, the number of users and satisfaction rating have been suggested as possible indicators of users' benefits (Loomis and Paterson, 2014). Focusing on recreational fishing, Hattam *et al.* (2015) proposed a number of indicators, such as the sea space available for recreation and the abundance and diversity of species of recreational interest. All in all, the combination of different indicators is preferred (Hernández-Morcillo *et al.*, 2013).

In the ecological sub-model developed in this study, the positive relation with oxygen saturation and negative relationship with ammonium concentration and metals, found for fish abundance and richness, is consistent with previous studies (Wright and Welbourn, 1994; Giardina *et al.*, 2009; Uriarte and Borja, 2009). In the Nerbioi, fish abundance and fish richness benefited from the reduction of ammonium loads and subsequent increase in oxygen in recent decades (Borja *et al.*, 2016b); however, once oxygen saturation was no longer a limiting factor (>80%) other elements, such as metal concentration, were found to affect negatively fish abundance.

In the social sub-model, the recreational fishing activity was analysed as a CES and measured in terms of number of users (i.e. active recreational fishers) and non-material benefits (i.e. fishers´ satisfaction). As satisfaction with the recreational fishing experience is known to be conditioned by catch and non-catch related aspects (Hunt, 2005; Beardmore *et al.*, 2013; Arlinghaus *et al.*, 2014, 2017; Chapter B), the overall satisfaction in our SDM was composed by both type of elements. Thus, the SDM variable "crowd satisfaction" represented the spatial restrictions and crowding, both considered as conditioners of recreational fishers' satisfaction (Griffiths *et al.*, 2017). Fish catches and environmental quality are also considered to contribute to fishers satisfaction (Arlinghaus, 2005; Griffiths *et al.*, 2017), and were represented in the SDM as "trip-catch satisfaction" and "fish richness satisfaction".

The SDM designed for the Nerbioi is a simplified version of the functioning of the estuary which translate into inherent limitations of the approach. First, the model was built considering the estuary as a unique entity; however, it is well known that there are important ecological differences between the inner and outer estuary (Borja *et al.*, 2006; Uriarte and Borja, 2009) known to condition also recreational fishing, with a general preference towards the outer estuary (Chapter B). Secondly, the temporal uniformity considered for fish abundance is due to the lack of information on seasonal variability, as this parameter is sampled only once a year. This is also an important limitation, considering that it is not known yet how temperature increase due to climate change will affect the abundance of species in Nerbioi. Third, regarding the ecological sub-model and to the best of found knowledge, the most important variables having direct effects on fish were included. However, certain variables that have not been included in this model (e.g. plankton) might affect fish abundance (Lynam *et al.*, 2010), ultimately affecting the recreational fishing activity. Finally, regarding the social sub-model, if more information on fisher's characteristics had been available, the analysis of the recreational fishing activity could have been done differentiating between mean motivations for fishing (i.e. catch and non-catch oriented fishers), which is known to affect overall fishing satisfaction (Arlinghaus, 2006). All these limitations, which conditioned the SDM design, affected the interpretation of the results obtained through the simulations. The results of the future scenarios are mainly limited in the social sub-model part, due to the scarce information available and little development of social research in the Nerbioi. For example, the increase in gaming fish in the marine outfall scenarios (SCE1 and SC5) had a limited effect in the trip-catch satisfaction, due to the consideration of fishing ability as a constant variable. However, fishing ability could increase in the estuary if more fish were available, causing an increase in the trip-catch satisfaction and consequently an increase in the overall satisfaction. The lack of information on how fishing ability changes in relation with available gaming fishes limited the results at this point.

Despite these limitations, the outputs of the SDM are of great interest for managers. The simulations revealed that accidental failures, management measures and global changes will affect the ecological equilibrium in the estuary, and ultimately the recreational fishing activity. Indeed, fish abundance and richness are likely to be affected by global changes such as climate change but also by local changes such as pollution, habitat degradation, etc. (Pasquaud *et al.*, 2015). The simulations revealed that the construction of the coastal submarine outfall for the ecological and sanitary improvement of the estuary can cause positive effects on recreational fishing (and likely for other recreational activities, such as beach recreation and bathing waters within the estuary (Chapter A)). On the other hand, the WWTP failure and dredging works can cause significant changes in ecological and social variables; with the estuary needing a variable time to recover from these stresses, as shown in different marine systems (Borja *et al.*, 2010a). The addition of climate change effects increased the variability and scalation of ecological and social variables, but it did not change the results significantly. Although changes in the social sub-model and related with the management of the fishing activity (e.g. species-specific catch restrictions, access limitations to fishing spots) can cause additional changes in recreational fishing and CES (Barrella *et al.*, 2016), this study did not consider them as the focus was placed only in environmental management changes that modified the ecological sub-model.

Research and management of marine ecosystems need to incorporate the ecosystem service paradigm (Arkema *et al.*, 2015) and despite its limitations, the SDM could be a useful tool for it. Firstly, SDM can help to overcome the classic management approach based on one-by-one variable analysis, due to its capacity to present a complete picture of complex social-ecological systems and the relationships between the variables in an easily understandable manner (Ostrom, 2009). Secondly, SDM facilitates the communication of modelling concepts and scientific results to managers (Elsawah *et al.*, 2017), as it presents the effects of the managing alternatives in all the components of the social-ecological systems. Consequently, SDM can assist environmental decision processes (Mavrommati *et al.*, 2013), even in cases where data are scarce, by using reliable scientific information to compare different managing options. The reliability of the results obtained will depend on the accuracy of the model structure and the quality of the information used to feed the model.

6. Conclusions

Using SDM, it has been demonstrated that nowadays in Nerbioi, after the removal of the chronic pressures within the estuary (i.e. untreated wastewater discharges), this system is able to cope with short-term acute pressures (i.e. accidental discharges, dredging). This result is a good response of the socio-ecological elements reflected in the scarce affection to the recovered ecosystem services and human benefits. Probably, the system is more resilient now to these short-term events and recovers faster than before, when chronic pressures were present, and is able to absorb the stress produced in recreational fishing. In addition, climate change seems to have no significant impact in recreational fishing, contrary to the significant effect found after the removal of human pressures (i.e. WWTP discharges). Both scientists and managers could look at the outcomes of SDM and carefully analyse the expected future trends on ecosystem services, considering possible changes. This study shows that doing so, environmental management decisions could be more successful upon their implementation.

chapter
d

MONETARY VALUATION OF BEACH RECREATION

Abstract

In the Nerbioi estuary (North Spain), the WWTP constructed in 1990 resulted in an abrupt decrease in water pollution and an opportunity for improved recreational experiences in the three beaches on the estuary. The monetary value of these recreational benefits was estimated using the travel cost method and compared, via a partial cost-benefit analysis, with the costs of beach maintenance. The travel cost models reveal that summer recreational trips to the three Nerbioi beaches have a value of 5.99, 7.06 and 8.09 € $trip^{-1}$, respectively. Visitor's profile and social characteristics influenced the models, while the effects of these variables also varied across beaches. Following a conservative approach, the aggregate recreational value of the estuarine beaches was estimated to be more than 3.5 million € $year^{-1}$. This economic benefit, obtained from summer estimates and focusing on one ecosystem service (i.e. beach recreation) from the multiple ones offered by the estuary, is sufficient to cover 100% of annual beach maintenance costs and 12% of the annual sewerage system running costs. The findings of this study highlight that investing in water sanitation projects such as WWTPs are not only important for the ecological recovery of degraded coastal environments, but also produce additional human benefits that are able to cover (at least) part of the running cost of these large capital investments.

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1. Introduction

Due to the large number of ecosystem services that they provide, estuaries are the marine ecosystems that support the widest range of human activities (Barbier *et al.*, 2011; Elliott and Whitfield, 2011; Barbier, 2017). Recreation is one of those estuarine human activities. It is considered to be a cultural ecosystem service (Hernández-Morcillo *et al.*, 2013), which is important for human well-being (Haines-Young and Potschin, 2010) and an input into coastal economies (Barry *et al.*, 2011). However, the estuarine ecosystem services are at risk due to their fragility and exposure to over-exploitation (Lotze *et al.*, 2006; Turner and Schaafsma, 2015).

Investing in environmental restoration could possibly help to halt degradation, conserve biodiversity and secure the supply of ecosystem services (Benayas *et al.*, 2009). The efficient use of scarce investments requires that the performance of the restoration project should be appraised in terms of the capital and running costs of the investments, and the yield in the form of ecological and human benefits (Pearce and Turner, 1990; De Groot *et al.*, 2013). If benefits/costs can be meaningfully expressed in monetary term, cost-benefit analysis can help to support decision making in estuaries restoration and maintenance (Turner, 2016). The monetary valuation of a spectrum of ecosystem services requires a wide range of tools and methods (De Groot *et al.*, 2012; Badura *et al.*, 2016; Costanza *et al.*, 2017). Among these tools, revealed preference and stated preference techniques are usually applied to estimate ecosystem services that lack a market value, such as recreation. Revealed preference methods infer values from observed behaviour, and thus, from actual choices people make within markets (Boyle, 2003; Ferrini *et al.*, 2014). Stated preference methods attempt to establish nonmarket values using survey questions, usually by asking respondents to choose between different scenarios (Brown, 2003; Metcalfe *et al.*, 2012).

Beach recreation, which is often an open-access and non-priced good, has been commonly valued in monetary terms using the travel cost revealed preference method (Parsons, 2003; Milcu *et al.*, 2013; Alves *et al.*, 2017). The travel cost method estimates the monetary value of recreational benefits to be at least what visitors are willing to pay to get to the recreation site (Farber *et al.*, 2002). The travel cost methodology allows for the inclusion of the social characteristics of visitors. This characteristic is relevant when the user´s profile is thought to be affecting the benefit obtained. Indeed, social characteristics can shape preferences and values towards ecosystem services (Martín-López *et al.*, 2012), which will condition the valuation of a specific benefit.

This investigation focuses on a case study of the beaches located inside the restored Nerbioi estuary. The aim is to examine the water quality restoration costs, including the construction of the main WWTP of Galindo, the beach maintenance costs, and the beach recreational benefits. Then a "partial" cost-benefit approach was adopted to focus only on beach recreation and beach maintenance costs. The ex post capital costs of the WWTP are treated as "sunk costs" i.e. a cost that has already been incurred and cannot be recovered. Strictly speaking the current and future running costs of the WWTP should be included in the cost-benefit analysis. However, it is difficult to apportion plant running costs to just beach recreation as the WWTP related-investment has benefited other ecosystem services, not just recreation/amenity benefits (e.g. improved fishing, biodiversity and human health benefits), but so far, these have not been monetarily assessed. Therefore, the cost-benefit analysis is restricted in its scope to a comparison of the beach recreation benefits with beach maintenance costs.

2. Nerbioi estuary restoration and beach recreation

From the second half of the 19th Century, the industry, urban and port developments in the estuarine villages transformed the area into one of the most important economic zones in Spain, mainly due to the development of iron and steel industries. However, the economic development also turned the estuary into the most polluted coastal area of northern Spain (Cearreta *et al.*, 2000, 2004) and limited the recreational use of its internal beaches (García-Barcina *et al.*, 2002).

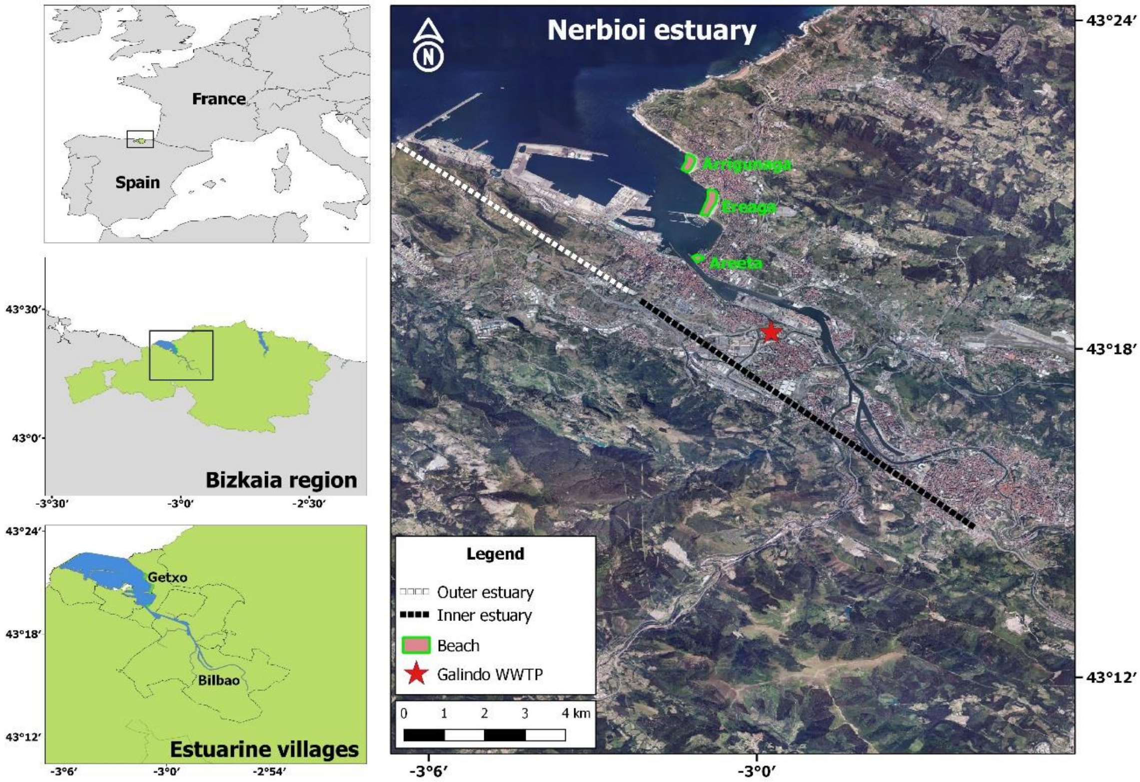

Figure D1 *- Location of the Nerbioi estuary at different geographical scales (within the Bay of Biscay and Bizkaia region); and location of the three beaches in the outer part of the Nerbioi estuary. Key: WWTP, Waste Water Treatment Plant of Galindo.*

After the approval of the water sanitation plan, the main investment in the estuarine recovery has been the implementation of the WWTP of Galindo (Figure D1). Between 1989 and 2017, 660 million € have been invested in sanitation infrastructures and wastewater treatment at this WWTP (Pascual *et al.*, 2012). Currently, the annual running costs of the WWTP of Galindo (including energy, maintenance, operation, etc.) have been estimated at more than 19 million €, while the ones of the peripherical systems (i.e. other WWTP that discharge in Nerbioi's tributaries, and therefore waters that arrive to the estuary) have estimated cumulative costs of more than 4 million € year^{-1} (Table D1).

Table D1 - *Annual costs (excluding VAT) of the sewage system (Waste Water Treatment Plant (WWTP) of Galindo and peripheral systems) and maintenance of beaches. Only the beach maintenance costs were used to perform the partial cost-benefit analysis. Information collated from: the local water management authority Bilbao-Bizkaia Water Consortium (CABB); Health Department of the Basque Country; official bulletins (Regional Government of Bizkaia and Basque Country Government) and public contracts available online (the web pages of the Basque Country Government and the city council of Getxo).*

	Total cost (€ year^{-1})
Sewage system running costs	**23,737,693**
• Galindo WWTP	19,393,958
• Peripheral WWTP systems	4,343,735
Beach maintenance costs	**670,558**
• Clean-up	227,642
• Bathing waters: sampling and analysis	3,527
• Rescue service	246,552
• Security (beach police)	58,996
• Infraestructure installation	31,834
• Coordination and general control	102,007

The implementation of the WWTP of Galindo and the decline of industrial activities at the end of the 20th Century allowed the progressive recovery of the estuarine waters (Cajaraville *et al.*, 2016), with a consequent improvement in the ecological quality (Borja *et al.*, 2016b), biological value (Pascual *et al.*, 2012) and positive effects in cultural ecosystem services such as recreational fishing and beach recreation (Chapters A and B).

Table D2 - *Main characteristics of the beaches. Sources: Regional Government of Bizkaia (2018); Regional Government of Bizkaia (personal communication) and AZTI (2011).*

Beach characteristics	**Areeta**	**Ereaga**	**Arrigunaga**	**Total**
Beach size (m^2)	6,000	56,448	42,704	105,152
Summer visitors (mean 2013-2015)	105,329	291,338	104,083	500,750
Bathing allowed after (year)	2009	2002	2002	

Focusing on beach recreation, three beaches can be found inside the estuary, all of them located on the right bank of the outer estuary and in Getxo village: (i) Areeta has the smallest sandy-shore and it is the closest to the inner part of the estuary; (ii)

Ereaga, the middle beach, has the largest sandy-shore area and receives the highest number of visitors during summer; and (iii) Arrigunaga is the outermost beach (Table D2). The bathing waters of these beaches recovered gradually, firstly in the external beaches, Ereaga and Arrigunaga, and more recently in Areeta, the innermost beach (Chapter A). The current maintenance costs of these three beaches have been estimated to be 670,558 € year^{-1}, including all-year-around clean-up and specific summer services such as rescue and security services, infrastructure installation, etc. (Table D1).

The mean profile of a visitor to Nerbioi beaches has been described in Chapter A as middle-aged, educated, mostly female, living in one of the estuarine villages. Their main motivations for going to the beach are sunbathing, relaxing and bathing. While the reasons for choosing to visit these specific beaches are their proximity to home, their accessibility and their tranquility. The main differences between beach visitors are: (i) in Areeta and Arrigunaga, there is a higher proportion of locals who reach the beach walking, while in Ereaga, there is a higher proportion of visitors who live in other estuarine villages and access the beach by car; and (ii) the worst perception of and attitude towards bathing waters are found among Areeta visitors, where a lower percentage of people practiced aquatic activities.

3. Methods

3.1. Partial cost-benefit analysis

A partial cost-benefit analysis was done to monetarily asses the beach recreation activity in the Nerbioi estuary. Cost-benefit analysis is an analytical tool to assess the welfare change attributable to an investment (Sartori and European Commission, 2015). Cost-benefit analysis can be used for valuing the expected benefits of alternative investments. After the implementation of a restoration project in a degraded system, a cost-benefit analysis can be used to assess the gain in ecosystem services benefits against the restoration investment cost (Bullock *et al.*, 2011). In the Nerbioi estuary, the social benefits, in terms of beach recreational opportunities, were compared with the costs necessary to maintain the beach recreation quality, grouped as “beach maintenance costs” in Table D1.

The cost-benefit analysis of the discounted flows of gains and losses is estimated for the 2016-2030 period and assessed through the Economic Net Present Value (ENPV) performance indicator. In Spain, there is no consensus on the discount rate that should be applied when performing cost-benefit analysis, although it usually varies between 4 and 6% (Souto Nieves, 2001; Cruz Rambaud and Muñoz Torrecillas, 2006; Sartori and European Commission, 2015). Therefore, the ENPV in Nerbioi was estimated with three different social discount rates: 3%, 4% and 5%.

To check the effect on the ENPV of a ±1% variation in benefits and costs, two sensitivity analysis were performed. If a 1% variation in the costs or benefits caused a variation in the ENPV >1%, the variable was considered critical (Sartori and European Commission, 2015). Afterwards, the switching values (i.e. the decreases in benefits and increases in costs needed for ENPV to equal zero) were estimated.

Finally, three future scenarios were simulated: (i) a decrease in population based on the future prospects by the Basque Statistical Institution (Eustat, 2014), which estimated a decrease of 5.6% for Bizkaia region between 2014 and 2026.; (ii) a continued rise in beach maintenance costs of 3.5% every two years, based on the increase registered for the period 2016-2018; and (iii) a combination of scenarios 1 and 2.

3.2. Cost estimation

The sewage system running costs (Table D1) were not included in the partial cost-benefit analysis, as they serve the region's population (García-Barcina *et al.*, 2006) and are linked to the provision of other ecosystem services and benefits, not just beach recreation.

Therefore, to perform the partial cost-benefit analysis in Nerbioi, the costs of beach maintenance (Table D1) were considered as the only direct costs attributable to the beach recreation activity. The monetary budgets of all the activities needed for the beach maintenance and services (i.e. beach running costs) represent the cost-opportunity of local government investments for maintaining the ecosystem recreation service in the estuary.

3.3. Valuation of beach recreation benefits

The second component needed to perform the cost-benefit analysis is the estimation of the benefits. Nonmarketed goods such as beach recreation can be valued using revealed preference methods, which infer values from observed actual behaviour (Champ *et al.*, 2003). In this study, the single site travel cost approach was selected, which is one of the most used revealed preference methods to estimate the economic use values of recreational activities (Parsons, 2003).

For the Nerbioi beaches, the annual benefits were calculated in two steps: (i) building single-site travel cost models for each beach; and (ii) estimating the aggregated surplus values based on the total number of trips to each beach in summer (Parsons, 2003). As estimates only consider visitors for a period of the year, the benefits will be underestimated. The data used to build the travel costs models were collected through a questionnaire distributed across the three beaches during summer 2016. The beach users who answered the questionnaire were selected in an aleatory way, and only people older than 16 years old were asked to complete the questionnaire. To obtain a balanced and representative sample of participants across beaches, the interviewer distributed questionnaires according to beach visitation rates (Table D2). A total of 426 questionnaires were collected in the three beaches. Detailed information on questionnaire design and distribution can be consulted in Chapter A.

The number of recreation trips to the beach taken by each respondent during summer season (i.e. from June to September) was established as the dependent variable of the travel costs function. The mean number of recreational trips during summer was estimated in 26 ± 22 trips.

Given the selected dependent variable count data, the travel cost models were built as Poisson regressions, and dependent on the travel cost (TC), travel cost to the substitute site (TCS), income (I) and several demographic variables (SC) (Parsons, 2003):

$$visits = f\ (TC, TCS, I, SC) \quad (1)$$

The first element conditioning the number of trips to the recreational site is the travel cost (TC). For each visitor, TC_i was defined as the sum of the travel expenses required to reach the beach (TE_i) and the time cost (tC_i):

$$TC_i = TE_i + tC_i \tag{2}$$

The first step to estimate the TC_i, was to calculate the distance and time from the origin to the destination. The origin was considered as the postal code from where the visitor began their journey to the beach (home, work, accommodation, etc.). The origin was defined as the coordinates of the centroid of the postal code area, while the destination was defined as the coordinates of the visited beach.

When the visitors reached the beach, walking, driving or cycling, the distance and time were calculated using the *ggmap* package (Kahle and Wickham, 2013) in R environment (R Core Team, 2017). When the visitors reached the beach by public transport, distance and time were calculated splitting them into three parts: (i) the walking distance and time from the origin to the nearest train or metro station; (ii) the distance and time in public transport from the origin station to the destination station; and (iii) the walking distance and time from the destination station to the beach. Walking distances and times for (i) and (iii), and driving distances and times for (ii) were calculated using the *ggmap* package (Kahle and Wickham, 2013). When public transport was used i.e. the underground, the distance in (ii) was estimated using Google Maps (2018), and time in (ii) was estimated using the information on travel times between stations (Metro Bilbao, 2018).

The travel expenses (TE_i) were estimated according to the transport used. When the visitor reached the beach walking or cycling, travel expenses were considered equal to zero. When the visitor reached the beach using public transport, the price of a round ticket from the origin to the destination was considered. If the visitor reached the beach driving, the travel expenses were estimated as:

$$TE_{iCar} = 2 \times (toll_i + D_i \times carCost) + parkfee \times tbeach_i \tag{3}$$

where $toll_i$ is the one-way price of the highway toll; D_i is the distance travelled; *carCost* is the average running cost per km of a vehicle in Spain (=0.35€)[2]; *parkfee* is the price per hour of car park (=1.07€, only applicable in Areeta); and $tbeach_i$ is the time expend at the beach. For those visitors who revealed to have reach the beach by car and accompanied, they were expected to share the costs and consequently, TE_{iCar} was divided by 2.

Following Fezzi et al. (2014), time costs (tC_i) for each visitor were calculated as:

$$tC_i = t_i \times tC_{mean} \quad (4)$$

where t_i is the time spend travelling from the origin to the destination by each visitor; and tC_{mean} is a constant that indicates the monetary value of the time spend travelling (€ min^{-1}), calculated as:

$$tC_{mean} = VTT \times {}^{I_{ind}}/_{wh} \times {}^{1}/_{60} \quad (5)$$

where I_{ind} is the mean available income per individual in the sample (=13,639 € year^{-1}); wh is the average annual working hours (=2080 h); and VTT is the average value of travel time per income fixed at $3/4$ (Fezzi *et al.*, 2014).

The second element conditioning the number of trips to a recreational site is the travel costs to a substitute site (TCS). The substitute site is usually considered as a site located nearby or with similar characteristics to the visited site (Parsons, 2003). It was considered that the three beaches of the estuary act as substitute sites for one another. Thus, from the two possible substitute beaches, the one located closest to the origin of each visitor was considered as the substitute site. TCS_i was estimated exactly as for the TC_i, replacing the destination coordinates by the ones of the substitute site.

Finally, the monthly household income (I_i) and other demographic variables (Table D3) were explored to be included in the travel cost models. Before incorporating them in the travel cost models, some of the demographic variables were transformed into dummy variables (Table D3). Later, all the demographic variables were tested

[2] The average running cost per km of a vehicle was estimated with the information from the report that estimated the average cost of maintenance of petrol and diesel cars in Spain in 2017 (http://aeaclub.org/cuanto-cuesta-tener-coche/), and considering the diesel/petrol car-fleet ratio in Spain (http://www.acea.be/statistics/article/Passenger-Car-Fleet-by-Fuel-Type)

against TC, TCS and $Income$ with different statistical test. This step was done to avoid multicollinearity in the regression models by discarding the variables that showed significant correlation. The variables, TC, TCS and $Income$ were compared with demographic variables using: (i) Spearman's rank correlation when the demographic variable was continuous or ranked-categorical; (ii) Mann-Whitney *U* test, to compare TC and TCS with dichotomous variables; or (iii) Chi-squared analysis, to compare $Income$ with dichotomous variables. The variables that showed correlation with TC, TCS and/or $Income$ were removed from further analysis. The independence between the remaining demographic variables was later checked with the Fisher's exact test.

A demand function for each beach was estimated as the Poisson regression models using the stats package in R environment (R Core Team, 2017). As the questionnaires were answered on-site, the dependent variable was corrected for selection bias as suggested by Parsons (2003). The basic models included the number of recreation trips to the beach taken by each respondent as the dependent variable, and TC, TCS and $Income$ as the independent variables. In the final models, the demographic variables were included.

The results of the Poisson models were used to calculate the aggregate access value for each beach (Parsons, 2003):

$$AV = TRIPS \times \hat{t} \quad (6)$$

where $TRIPS$ is defined as the total number of day trips to the beach during summer and calculated as the mean number of visits for the period 2013-2015 (Table D2); and $\hat{t}$ is the average per-trip value in the Poisson model. After Parsons (2003), $\hat{t}$ is defined as:

$$\hat{t} = {}^{1}/_{-\hat{\beta}_{tcr}} \quad (7)$$

where $\hat{\beta}_{tcr}$ is the coefficient for TC on the Poisson models.

Table D3 *- Income and demographic variables considered in the travel cost models. Mean±SD and % columns were adapted from Chapter A.*

Variable	Description	Type	Categories		Total		Areeta		Ereaga		Arrigunaga	
					Mean±SD	%	Mean±SD	%	Mean±SD	%	Mean±SD	%
Income	Monthly income. Ranks were fixed with the minimum wage in Spain in 2016 and the mean wage in estuarine towns (€ $month^{-1}$) (Eustat, 2016)	Categorical (rank)	1	<655		15		13		20		5
			2	655-1,395		51		46		54		48
			3	>1,395		34		41		26		47
Age	Age of the respondent (years)	Continuous			42±16		44±16		41±16		42±16	
Gender	Gender of the respondent	Dichotomous	0	Female		74		83		70		77
			1	Male		26		17		30		23
Education	Maximum education achieved by the respondent	Dichotomous	0	Secondary or lower		52		45		60		40
			1	Higher education		48		55		40		60
Employment	Employment status of the respondent	Dichotomous	0	Others (retired, student, unemployed)		44		54		44		38
			1	Employed		56		1		56		62
Origin	Hometown of the respondent	Categorical (rank)	1	Getxo village		37		42		19		69
			2	Other estuarine villages		48		48		58		20
			3	Bizkaia region		10		4		15		5
			4	Farther (Spain, abroad)		5		6		8		6
Beachtime	Expected time in the beach (hours)	Continuous			3.3±1.4		2.8±1.1		3.4±1.4		3.5±1.5	
Company	Whether the respondent come to the beach accompanied	Dichotomous	0	No		27		37		26		19
			1	Yes		73		63		74		81
Aquatic sports	Whether the respondent practice any aquatic activity in this beach	Dichotomous	0	No		37		56		35		24
			1	Yes		63		44		65		76
Overall satisfaction	Satisfaction level of the respondent with the trip to this beach	Dichotomous	0	None or little satified		7		10		3		12
			1	quite or totally satisfied		93		90		97		88
Seasons coming	How long has the visitor been coming to this beach?	Categorical (rank)	1	(1-6 years)		28		34		29		19
			2	(6-20 years)		31		27		32		33
			3	more than 20 years		41		39		39		47

4. Results

4.1. Valuation of beach recreation benefits

From the 426 questionnaires collected, 400 could be used to perform the travel cost analysis (93 in Areeta, 209 in Ereaga and 98 in Arrigunaga). The mean *TC* value was 5.63 € $trip^{-1}$ (min. 0.73, max. 44.89 € $trip^{-1}$) while mean *TCS* was estimated at 6.40 € $trip^{-1}$ (min. 0.21, max. 43.44 € $trip^{-1}$).

In the basic Poisson regression models (i.e. built only with *TC, TCS* and *Income*), the *TC* estimate was negative and significant at the three beaches (Appendix D Table 1). The *TCS* estimate was significantly positive in Ereaga and Arrigunaga, while in Areeta, it was significantly negative. The significant negative influence of *TCS* could be indicating that neither Ereaga nor Arrigunaga act as substitute sites for Areeta. Therefore, in the next step, where demographic variables were incorporated in the models, *TCS* was considered equal to 0 for Areeta. Also, in Areeta surveys, it was detected that some respondents could be visiting the beach as part of a multiple purpose trip, especially when they arrived using a transport different from walking. In order to avoid an overestimation of the travel cost and consequently, an overestimation of the aggregate surplus value in Areeta, only the visitors who reach the beach walking were used to build the model (n=59).

A total of seven demographic variables (i.e. *age*, *gender, education, employment, origin, beach time and seasons coming*) were found to be significantly correlated with TC, TCS and/or $Income$ (p-value<0.05 for the different tests performed) (Appendix D Table 2) and therefore, removed from further analysis to avoid multicollinearity. The remaining demographic variables were *company*, *aquatic sports* and *overall satisfaction*. The Fisher's tests confirmed that these three variables were not significantly correlated between them and were included in the definitive Poisson models.

In the definitive Poisson regression models, the number of trips decreased as TC increased, while the number of trips taken to Ereaga and Arrigunaga increased as TCS increased (Table D4). The demographic variables had different effects in each beach: in Ereaga, people with higher *Income*, those who came to the beach accompanied and satisfied visitors (i.e. *overall satisfaction* equal to 1), took a higher number of trips to the beach, while the effect of *aquatic sports* was the opposite (i.e. people practicing aquatic sports took less trips than those who did not practice any aquatic sports). In Areeta and Arrigunaga, the effect of *Income* and *aquatic sports* was opposite to the effect in Ereaga, meaning that people practicing aquatic sports took more trips to these beaches and that the number of visits decreased as the income increased. The *overall satisfaction* in Arrigunaga had the same effect as in Ereaga, meaning that satisfied visitors took more trips, while in Areeta the effect was the opposite.

The lowest consumer surplus and aggregate access value were estimated for Areeta (5.99 € trip^{-1} and 630,710 € year^{-1}, respectively). Arrigunaga had the highest consumer surplus (8.09 € trip^{-1}) and an aggregate value of 842,549 € year^{-1}. In Ereaga, the consumer surplus was valued in 7.06 € trip^{-1}, while the aggregate access value was 2,057,822 € year^{-1}, the highest among the three beaches.

***Table D4 -** Poisson models for recreational trips to Areeta, Ereaga and Arrigunaga and the single and aggregate surplus. Key: *** = p-value<0.001; **=p-value<0.01; *=p-value<0.05; n.s.=not significant; WTP= willingness to pay.*

	Areeta				**Ereaga**				**Arrigunaga**			
	Estimate	**Std. Error**	**z value**		**Estimate**	**Std. Error**	**z value**		**Estimate**	**Std. Error**	**z value**	
(Intercept)	3.798	0.111	34.079	***	2.997	0.109	27.413	***	3.624	0.107	33.830	***
Travel Cost (TC)	-0.167	0.032	-5.145	***	-0.142	0.016	-8.794	***	-0.124	0.017	-7.419	***
Travel Cost to Substitute (TCS)	-	-	-		0.098	0.015	6.401	***	0.054	0.022	2.458	*
Income (655.2€ - 1394.93€)	-0.278	0.090	-3.104	**	0.087	0.040	2.205	*	-0.858	0.073	-11.822	***
Income (> 1394.93€)	-0.222	0.083	-2.665	**	0.214	0.045	4.773	***	-0.691	0.072	-9.536	***
Company (yes)	-0.008	0.047	-0.170	n.s.	0.101	0.038	2.691	**	0.022	0.049	0.443	n.s.
Aquatic sports (yes)	0.538	0.050	10.662	***	-0.157	0.030	-5.238	***	0.411	0.053	7.741	***
Overall satisfaction (quite or total)	-0.172	0.070	-2.462	*	0.342	0.092	3.716	***	0.313	0.066	4.771	***
Model paramaters												
Observations	59				205				98			
Pseudo R^2 (McFadden)	0.153				0.166				0.185			
WTP												
Consumer surplus (€ $trip^{-1}$)	5.99				7.06				8.09			
Aggregate access value (€ $year^{-1}$)	630,710				2,057,822				842,549			

4.2. Partial cost-benefit analysis

Considering the aggregate access values as the benefits returned to society and the beach maintenance costs as the costs directly attributable to beach recreation, it is estimated that in total, the three beaches provide ~2.9 million € year^{-1}. These benefits need now to be compared with costs and both discounted over the chosen time horizon. Assuming that annual running costs and benefits are constant for the period 2016-2030, the ENPVs ranged between 29.5 and 33.9 million € year^{-1}, given the highest (5%) and the lowest (3%) SDR were applied, respectively (Table D5). After the sensitivity analysis, the beach recreation benefits were found to be a critical variable, as a 1% decrease in 2016 caused a decrease in ENPV of 1.24%. However, in order to nullify the benefits (ENPV=0), an 80% decrease in benefits or 412% increase in costs need to be observed.

***Table D5 -** Results of the cost-benefit analysis performed for 2016-2030. Economic Net Present Values (ENPV) were estimated for three social discount ratios (SDR): 3%, 4% and 5%. Results of the sensitivity and scenario analysis are reported in terms of new ENPV (column: ENPV) and in terms of difference between current ENPV and new ENPV (column: %).*

	Current ENPV (€)	**Sensitivity analysis**				**Switching values (ENPV=0)**		**Scenario analysis**					
		↓ 1% benefits		**↑ 1% costs**		**↓% benefits**	**↑% costs**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		ENPV (€)	*↓%*	*ENPV (€)*	*↓%*			*ENPV (€)*	*↓%*	*ENPV (€)*	*↓%*	*ENPV (€)*	*↓%*
SDR 3%	33,928,228	33,506,690	1.24	33,845,972	0.24	80.5	412.5	32,840,652	3.2	33,152,956	2.3	32,065,380	5.5
SDR 4%	31,600,183	31,207,584	1.24	31,523,586	0.24	80.5	412.5	30,615,217	3.1	30,902,579	2.2	29,917,613	5.3
SDR 5%	29,501,700	29,135,186	1.24	29,430,203	0.24	80.5	412.6	28,607,800	3.0	28,872,794	2.1	27,978,894	5.2

The future reduction of the local population and increase in beach maintenance costs simulated through three scenarios caused ENPV reductions of >2% (Table D5). The lowest reduction was registered in scenario 2 (i.e. increase in beach maintenance costs), where ENPV decrease 2.1-2.3%. The highest ENPV reduction (5.2-5.5%) was predicted in scenario 3, where a combination of the effects of population decrease and maintenance cost increase were simulated. Scenario 1 (i.e. population decrease) caused an intermediate reduction in ENPV of 3.0-3.2%.

5. Discussion

A partial cost-benefit analysis was performed in the restored Nerbioi estuary to check if the nonmarketed benefits obtained through beach recreation can cover the current costs needed to deliver such a cultural ecosystem service. By building single-site travel cost models, the monetary value of beach recreation was estimated, in an area where the water quality and ecological conditions have improved significantly in the last 25 years (Uriarte and Borja, 2009; Cajaraville *et al.*, 2016).

The Poisson regression models built, revealed that significant differences exist between the recreation activities in the three beaches. The significant negative value of the *TCS* in Areeta indicated that there was not a real substitute site for this beach; which could be related with the characteristics of the beach and with the user's profile. Areeta is, among the three estuarine beaches, the one with the highest urbanized surroundings and the worst water-quality conditions (Chapter A). These characteristics could be behind the differences found on the visitor's profile. Indeed, Areeta visitors are known to be older and spent significant less time on the beach than was the case in the other beaches (Chapter A). Based on that previous study and the results obtained in the travel cost models, it was concluded that the recreational activity in this beach is different to the recreational activity in Ereaga and Arrigunaga.

Comparing the travel cost models of the three beaches, it was found that certain demographic characteristics had an opposite effect on the number of summer trips, which could be related with the specific characteristics of the beaches and the social profile of the visitors. Thus, a higher income in Ereaga had a positive effect on the number of trips, in line with travel cost studies in other areas (Fezzi *et al.*, 2014; Ezebilo, 2016), while the effect was the opposite in the other two beaches. This could be related with the higher number of non-locals found in Ereaga, which translates into a higher economic effort incurred every time they want to visit the beach (Prayaga, 2017). Therefore, those with higher incomes might be able to travel more frequently here. In Areeta and Arrigunaga, where the effect of the increase in income was the opposite, the reason could be related with the high percentage of local visitors from Getxo. The high percentage of locals in Areeta and Arrigunaga could have made the income variable effect to reverse, as wealthier locals can spend more traveling to farther and more appealing beaches. Indeed, the region has several beaches located nearby that have maintained historically better water quality conditions than the beaches in the Nerbioi. The variable company was only found to be significant in Ereaga, and the effect was positive; the reason behind this effect could be again related to the fact that they travelled from further away. All these demographic characteristics translated into differences in the use of the goods, highlighting the importance of analysing the social demographic variables when performing ecosystems service valuation (Martín-López *et al.*, 2007).

The high proportion of locals and of visitors living in the nearby villages who reach the beaches walking or using public transport have conditioned the results of the travel costs models. The travel cost method values the analysed good considering how much the visitor must invest in terms of the time and trip costs to reach the recreational site; therefore, expenses are lower for those living near the visited site than for those living farther away (Parsons, 2003; Voke *et al.*, 2013). Therefore, in Nerbioi beaches most of the visitors spent relatively low amounts of money in each trip and time effort to enjoy the good. However, the travel cost value could be an underestimation of the good, as enjoying recreation in local areas could be important in health/well-being and cultural terms, such as cultural identity and place attachment (Hoyos *et al.*, 2009; Loomis and Paterson, 2014). These additional values are not captured by the travel cost models, so care should be taken when interpreting the estimated benefits.

The relatively low travel cost in the Nerbioi beaches is also highlighted when comparing the results of this study with previous studies carried out in other beaches in

Spain, such as in the Mediterranean coast (Ariza *et al.* (2012) estimated the consumer surplus in 17.9-42.6 € in summer and 9.7-29.8 € in winter) or the south-Atlantic coast (Alves *et al.*, (2017) estimated the consumer surplus between 42.35 and 73.27 € in summer and 51.71-100.85 € in winter). This difference could again be an effect of the high percentage of local visitors in the Nerbioi, compared with the Mediterranean and south-Atlantic coasts, where 'sun and beach tourism' is more popular and historically attracts the highest number of visitors to Spain (Cànoves-Valiente *et al.*, 2016). Indeed, the north-Atlantic coast, where Nerbioi estuary is located, has different climatic conditions than other coastal areas in Spain, with less sunshine hours during summer, lower overall temperatures and higher rainfall than the south-Atlantic and Mediterranean coasts (Sanchez-Lorenzo *et al.*, 2007). This translates into worse bathing water conditions (Aragonés *et al.*, 2016) and worse general conditions for beach recreation. Consequently, the Nerbioi beaches received less visits during summer than other beaches in Spain, which translated into lower aggregate surplus values. Furthermore, the aggregate surplus values were estimated only with the recreational trips taken during summer; however, these beaches are in urban locations and they attract visitors all year around, which will increase the aggregate surplus values. The lack of data on the number of beach visitors in winter impeded the calculation of the aggregate surplus values for this period. Tthe probable underestimation of the beach recreation benefits in Nerbioi is considered a good practice, as afterwards, the aggregate surplus values were used to perform a cost-benefit analysis.

Still, the aggregate surplus estimations in the three beaches covered the total annual beach maintenance costs and 12% of the sewerage system running costs (Table D1). This is a substantial amount, considering that as mentioned before, the benefits were estimated adopting a cautionary approach, as they were calculated considering "summer visitors" only and focusing on one ecosystem service. Indeed, the analysis focused on beach recreation, even though the restored estuary is providing multiple benefits (including health/well-being) to local and visitors. Some of these additional benefits, for example recreational fishing, are highly dependent on water quality and therefore, they were only recovered after the improvements registered in the last decades (Chapter B). Most recently international sport competitions have taken place in the estuary with important economic revenues for the area. Other economic activities, such as the real estate market in the estuarine banks, have likely benefited from the rehabilitation of the Nerbioi estuary, as it has happened in other estuaries and coastal wetlands (Earnhart, 2001; Pendleton, 2010). Finally, the restoration of the Nerbioi estuary attracted the attention of multiple scientific marine disciplines, such as water and sediment pollution, biology and ecology contributing to the scientific knowledge and education; some examples are: (Cearreta *et al.*, 2000; Cearreta and Leorri, 2000; Belzunce *et al.*, 2001; Borja *et al.*, 2006; García-Barcina *et al.*, 2006; Uriarte and Borja, 2009; Pascual *et al.*, 2012; Cajaraville *et al.*, 2016). Some of the actual benefits could have been present for local visitors prior to the restoration process. Indeed, some of the beach recreation activities are non-water-quality dependent (e.g. sunbathing or sand sports such as volley ball), and these activities could be economically significant. To the best of found knowledge, there is not information available on beach use and activities prior to the water quality improvement; however, considering that most of the current visitors revealed that they practice aquatic activities in these beaches and that bathing is one of the main motivations to visit them (Chapter A); it can be claimed that the water quality beaches improvement has been crucial for the current high number of visitors found in Nerbioi.

The Nerbioi estuary is important in terms of ecosystem services, as well as an important area for the region in economic and social terms (Casado-Arzuaga *et al.*, 2013). Many economic activities take place along its two banks and in the ports located inside the estuary. In addition, 61% of the Bizkaia region's population lives in one of the nine estuarine villages. Therefore, the three beaches studied here offer the nearest beach recreational opportunity for a high number of people who chose to visit them mainly because of their proximity to home and their good accessibility (Chapter A).

The expected decrease in the region's population will cause a decrease in benefits, but according to the results this reduction will not change the sign of the cost/benefit rate. Despite the likely reduction of local population, the promotion and advertising of the tourism sector by public institutions in the region and the existence of other recreational opportunities nearby (Casado-Arzuaga *et al.*, 2014) are likely to boost the number of non-local visitors and halt the expected decrease in beach recreation benefits.

Measuring in monetary terms the benefits provided by environmental goods has proved to offer useful information for policy makers and public (Garrod and Willis, 1999; Turner *et al.*, 2010); and this also holds true for the Nerbioi estuary. The nonmarketed benefit analysis performed in this study could be of special interest for all the institutions that contributed to the rehabilitation of the Nerbioi estuary. It indicates that decision support systems could use economic valuation and other evaluation methods to value the range of ecosystem services benefits restored thanks to the improvement of water quality. Future studies that aim at estimating market and nonmarket benefits provided by the recovered Nerbioi estuary could help to draw a more complete picture of the outcomes of the restoration project (set up nearly 30 years ago) in the area.

To perform an economic valuation of the ecosystem services gained after the implementation of a restoration project can provide easy-to-communicate information on the project´s outcomes. As seen for the Nerbioi beaches, the social characteristics of the users can influence the final monetary valuation of the ecosystem services, so the method to perform such a valuation should be chosen according to the type of ecosystem service to be valued and to the available information on service users.

6. Conclusions

The beach recreation service recovered after the restoration of the Nerbioi estuary has a significant monetary value, according to the conservative benefit estimation performed in this study. The beach recreation benefits were able to cover the whole costs of beach maintenance plus an important percentage of the sewage scheme system costs. The use of econometric tools such as travel cost models to value nonmarketed coastal ecosystem services provides important information that can be easily communicated to policy-makers and stakeholders. Travel cost accounts only for the used values and ignored additional benefits that could exist from the enjoyment of these areas, so results should be used with caution. Also, users’ profiles have proved to influence the final economic value, even when the analysed areas are so close to one another. If possible, travel costs results should be combined with information collated using other valuation techniques.

chapter e

MONETARY VALUATION OF RECREATIONAL FISHING

Abstract

Recreational fishing is considered a cultural ecosystem service, important in terms of the socio-economic benefits that it provides. In the Nerbioi estuary (northern Spain), investments in water treatment and the closure of polluting industries have led to several benefits such as improvements in water quality, fish abundance and richness and recreational fishing activity. Currently, this activity is performed along the whole estuary including areas that previously were severely polluted. Valuing the benefits of recreational fishing is crucial to support the management of the estuary. The economic valuation is performed using a multi-site travel cost analysis. In addition, future scenarios where accessibility and environmental conditions change, were simulated to analyse the effect on welfare. Results indicate that each recreational trip in Nerbioi has a use value of 14.98 €, with an aggregate value of 1.12 million € year^{-1} for the whole recreational fishers´ community. The simulated scenarios suggest that further environmental improvements would have a positive effect in the activity, increasing the current welfare by 7.5-11.5%. Opposite, worsening of environmental conditions and accessibility could translate into a welfare reduction up to 71%. The monetary use value of recreational fishing partially covers (4.7%) the costs of maintaining the environmental quality of the estuary (i.e. treatment plant maintenance costs).

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1. Introduction

Ecological restoration can reverse the environmental degradation caused by human activities, resulting in a positive impact on ecosystem services (Benayas *et al.*, 2009; Matzek, 2018). Consequently, an improvement on ecosystem services will have positive outcomes for human well-being, which is known to depend, to some extent, on the natural environment (Summers *et al.*, 2012).

With 43% of the world´s population living no further than 50 km from an estuary (O'Higgins *et al.*, 2010), estuaries have become some of the most degraded ecosystems (Lotze *et al.*, 2006). Numerous human activities have historically developed around them (Barbier *et al.*, 2011), increasing pressures, generating impacts and compromising their ecological integrity and capacity to provide ecosystem services (Lotze *et al.*, 2006; Barbier, 2017). Investing on restoration of degraded estuaries could help to enhance their ecological status, to recover the ecosystem services they provide, and likely contribute to improve human well-being.

When located in urban areas, healthy estuaries are considered "blue spaces" from which inhabitants can benefit in multiple ways (e.g. recreation, social interactions) (Bullock *et al.*, 2018) and translate into physical and mental health benefits (Nutsford *et al.*, 2016). Recreational fishing is one of the many recreational activities taking place in estuaries, important in terms of the socio-economic benefits that provides (Pita *et al.*, 2017). It is a cultural ecosystem service (Ghermandi *et al.*, 2012), which, according to CICES, are the non-material outputs of ecosystems that affect physical and mental states of people (Haines-Young and Potschin, 2018). Recreational fishing involves the consumption of material (i.e. catch), and therefore, it is considered a cultural-consumptive service (Ghermandi *et al.*, 2012).

The benefits of recreational fishing can be assessed in monetary terms, for which nonmarket valuation techniques are considered more adequate than market valuation techniques (Viana *et al.*, 2017). First, because even if it involves the consumption of fish, to base the economic value entirely on the market price of fish-catches would not capture the social benefits that fishers obtain through the practice of the activity. Indeed, the motivations for practicing recreational fishing have been described as a combination of non-catch and catch-related motives (Fedler and Ditton, 1994). Similarly, in the overall satisfaction of fishing, both catches and social aspects are important (Arlinghaus, 2006; Chapter B). Second, nonmarket valuation techniques are preferred because they estimate consumer values.

The nonmarket valuation techniques available to assess the recreational benefits are classified in two groups: stated preference and revealed preference methods. Stated preference are direct methods, as user´s are asked how much they are willing to pay or receive for an environmental quality change, while the later are indirect methods, because they use user´s actual behaviour to build models (Adamowicz *et al.*, 1994).

Travel cost is a well-established revealed preference technique, commonly applied to value recreational uses of the environment (Boyle, 2003). The simplest travel cost models are the single-site models, which estimate access value of a recreational site based on the number of trips demanded by a person in a season and the trip cost of reaching the site (Parsons, 2003). However, these models are unable to account for changes on natural settings that can affect users´ recreational choices.

As recreational fishers choose the fishing site considering expected catches and a wide set of factors (e.g. environmental conditions, infrastructures) (Arlinghaus *et al.*, 2017), incorporating those variables into the econometric models can provide more accurate estimates. The multi-site Random Utility Models (RUM) consider the site-characteristics known to influence the frequency of the recreational trips and are preferred over single-site models because they allow the analysis of value change when those characteristics change (Parsons, 2003). Indeed, RUMs have often been used to analyse the variables that influence decision on where to fish of both professional and recreational fishers (Hutniczak and Münch, 2018; Pokki *et al.*, 2018).

The use of RUMs for valuing recreational fishing benefits could be specially interesting in restored ecosystems. Environmental factors conditioning the recreational activity could have improved after restoration (Chapter C), and if the RUM contains those improved factors, an economic value can be assigned to the improvement, establishing a direct link to the social benefits. Monetary valuation of recreational benefits on restored ecosystems (i.e. valuing changes in recreational ecosystem services) is also useful for assessing the outputs of a restoration project (De Groot *et al.*, 2013). Managers could use the monetary estimate of the benefits to design future management measures, accounting for all the loss and gains that each alternative will involve.

The objective of this study is to assess in monetary terms the current and future recreational fishing benefits generated in the restored Nerbioi estuary. Recreational fishing in Nerbioi has been described as an important social activity highly dependent on the environmental amelioration (Chapter B); performing an economic valuation of the activity could complement these data. To achieve the objective, a multi-site RUM is built. The results of the econometric model are used to value in monetary terms the gain/loss of recreational fishing benefits as consequence of future plausible changes in estuarine environmental and access conditions.

2. Methods

2.1. Nerbioi estuary restoration and recreational fishing

The Nerbioi estuary had recovered progressively the water quality (Borja *et al.*, 2006, 2010a), biotic components (Uriarte and Borja, 2009; Pascual *et al.*, 2012) and several cultural ecosystem services, such as beach recreation and recreational fishing (Chapters A and B).

For this chapter, the estuary was divided in five segments (SEG), two in the outer estuary (SEG1 and SEG2) and three in the inner estuary (SEG3, SEG4 and SEG5) (Figure E1), following previous studies on ecological status (Uriarte and Borja, 2009) and recreational fishing (Chapter B). Chapter B analysed recreational fishing patterns within the same segments of the Nerbioi estuary, crossing historical biotic and abiotic data and recreational fishers' behaviour and perceptions obtained from a survey. The activity was found to be mainly practiced by locals, middle-aged males whose motivations were more social-oriented than catch-oriented. Significant differences on fishing patterns between SEGs were found, with fishers preferring to fish from shore and in the outer part, having fished in the inner part over more recent years, after restoration of the estuary.

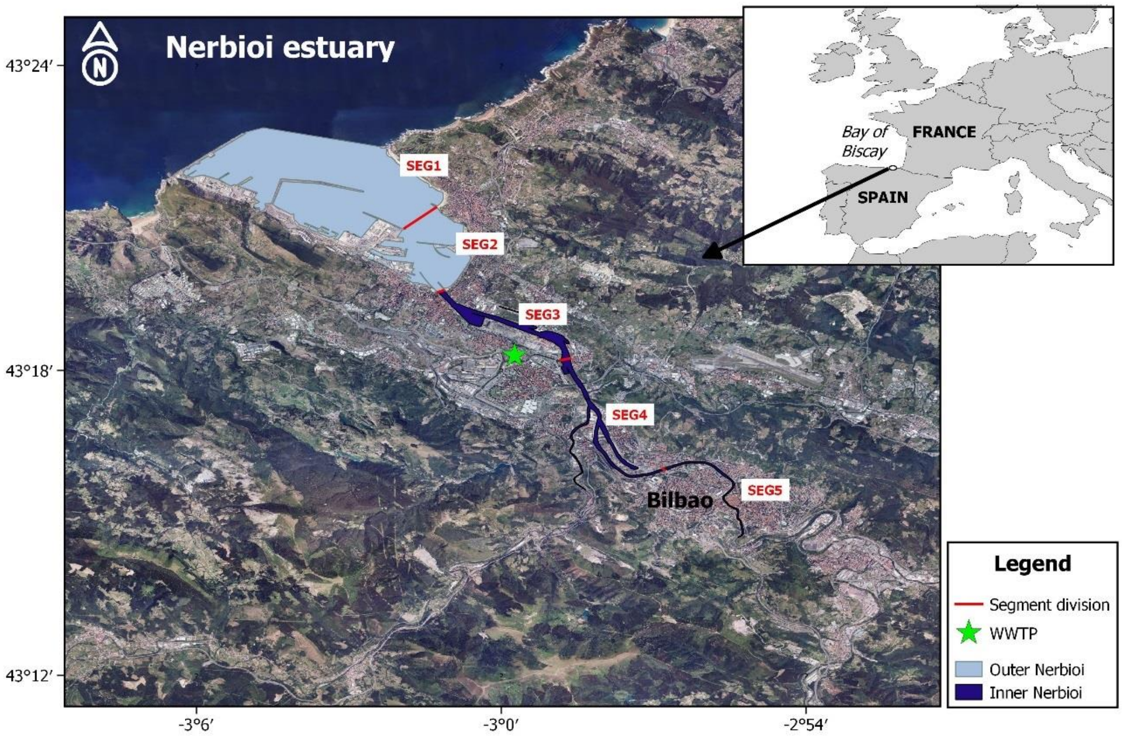


Figure E1 *- Location of Nerbioi estuary within the Bay of Biscay. Estuary division in segments (SEG), used as alternatives on the Random Utility Model. WWTP: Waste Water Treatment Plant.*

2.2. Multi-site random utility travel cost model

To perform the economic valuation of the recreational fishing in Nerbioi, a multi-site RUM-travel cost model was defined. Contrary to the single-site models, where the dependent variable is the quantity demanded (i.e. number of trips to a recreational site), in RUMs, the dependent variable is the site selected (Parsons, 2003).

The information required to define the model was retrieved from previous studies that analyse recreational fishing in the estuary (Chapters B and C) and the entire Basque Country (Ruiz *et al.*, 2014). Environmental data from two monitoring networks (Borja *et al.*, 2016b) were also used in the model. The coefficients of the RUM were used to estimate in monetary terms the effect that environmental and access changes can have in the current recreational fishing benefits.

2.2.1. Description of the model

The theoretical basis of the RUM is that individuals make choices under a "utility maximisation framework", and that individual´s utility (U_i) for a given site is a function of observable (V_i) and unobservable (ε_i) characteristics (McFadden, 1973):

$$U_i = V_i + \varepsilon_i \tag{1}$$

As a nonmarket valuation technique, RUM can be applied in travel cost recreational demand analyses, assuming that the individual (i) chooses a site (j) based on the cost incurred to get there (TC_{ij}) and site-specific characteristics (Z_j) (Pendleton and Mendelsohn, 2000; Haab and McConnell, 2002; Viana *et al.*, 2017). Therefore, the utility associated with visiting a site is a function of the travel costs (TC_{ij}), site specific characteristics (Z_j) and a random error term (e_{ij}):

$$U_{ij} = f\left(TC_{ij}, Z_j\right) + e_{ij} \tag{2}$$

To specify a RUM for recreational fishing in Nerbioi, the five SEGs defined in Chapter B were used as the alternative-sites. It was assumed that the respondents compared the SEGs using site-specific characteristics and travel cost to reach the sites, choosing the option that maximized the utility.

Based on these premises and with the information on the number of trips year^{-1} that each fisher makes to each SEG, a conditional logit model was specified (McFadden, 1973). Precisely, each trip made by each respondent over a year was considered as a single choice occasion and assumed not to be conditioned by previous choices made. The conditional logit model was calculated with the *mlogit* package (Croissant, 2018) in software R (R Core Team, 2017).

The parameters of the model were used to estimate the relative WTP of each attribute known to affect the site chosen:

$$WTP_x = {}^{\beta_x}\!/_{-\beta_{tc}} \tag{8}$$

where β_x is the coefficient for the *x* attribute, one of the site-specific characteristics (Z_i), and β_{tc} is the coefficient of the travel cost. The "maximum expected trip utility" (EU^0) was estimated for each trip as:

$$EU^0 = ln\{\sum_{ij}^{s} exp(\beta_{tc}TC_{ij} + \beta_Z Z_j)\} \quad (9)$$

where β_{tc} and β_z represent the coefficients of the travel cost (TC_{ij}) and the site-specific characteristics (Z_j), respectively. The mean maximum utility value per trip in monetary units ($\bar{s}$) was estimated dividing the sample mean "maximum expected trip utility" ($\overline{EU}^0$) by the travel cost coefficient:

$$\bar{s} = \overline{EU}^0 / -\beta_{tc} \quad (10)$$

The aggregated value per recreational fisher ($\bar{S}$) was calculated as:

$$\bar{S} = \bar{s} \cdot T \quad (11)$$

where T is the average seasonal number of trips per recreational fisher, and fixed to 30 (Ruiz *et al.*, 2014; Chapter C). The aggregated seasonal value was calculated as:

$$AS = \bar{S} \cdot POP \quad (12)$$

where *POP* is the recreational fishers´ community in Nerbioi, estimated in 2,500 fishers (Chapter C).

2.2.2. Travel cost estimation

The travel cost was calculated using data gathered from a survey administered to recreational fishers in Nerbioi (Chapter B). The questionnaire was distributed between in 2016 using two approaches: (i) on-site face-to-face interviews (*in situ* sampling) and (ii) contacting fishing clubs and federations (*ex situ* sampling). A total of 146 questionnaires were collected (50 *ex situ* and 96 *in situ*); more details on questionnaire design and distribution can be found in Chapter B.

The travel cost for each respondent in each SEG was estimated using the survey questions regarding: (i) the fishing experience in each of the SEG (if they fish nowadays in the SEG and how many days year^{-1}); and (ii) questions about the specific day when they answered the questionnaire (if they fished in the estuary that day, which was the fishing site destination, the origin and the transport used to reach it).

For each respondent *i* and each alternative j, travel cost (TC_{ij}) was defined as the sum of the travel expenses required to reach the fishing site (TE_{ij}) and the time cost (tC_{ij}):

$$TC_{ij} = TE_{ij} + tC_{ij} \quad (13)$$

The origin was unique for each respondent and considered as the coordinates of the centroid of the postal code from where they began their journey (e.g. home, work) to the five alternatives. The first destination estimated was the real destination, i.e. the SEG visited by the respondent the day when answering the questionnaire. The coordinates for the remaining alternatives were fixed selecting the two most popular fishing spots in each SEG, one per estuarine bank, with the information collected in Chapter B. When various fishing spots in the same SEG and estuarine bank received similar number of visitors, the one that was better connected by road and by public transport was selected. Also, mobility between the two banks of the estuary is easy and it would not be uncommon for the same fisher to move from one bank to the other to practice fishing. However, in order to keep the number of alternatives fixed to five (i.e. one per SEG), it was assumed that each respondent will remain in the same bank (i.e. bank of the real destination) and reach all the SEGs using the same transportation.

The distance and time were calculated using the *ggmap* package (Kahle and Wickham, 2013) in R environment (R Core Team, 2017) following the methodology explained in Chapter D. The travel expenses (TE_i) were dependent on the type of transport used to reach the fishing site; therefore, considered equal to zero when the fisher walked or cycled. When public transport was used, the price of a round ticket from origin to destination was considered. If the visitor reached the fishing site driving, the travel expenses were calculated as:

$$TE_{ijCar} = 2 \times \left(toll_{ij} + D_{ij} \times carCost\right) + parkfee_j \times tfishing_{ij} \quad (9)$$

where $toll_{ij}$ is the one-way price of the highway toll; D_{ij} is the distance travelled; *carCost* is the average running cost per km of a vehicle in Spain (=0.35€, see Chapter D section 3.3.); *parkfee* is the price per hour of car park (=0.53€, only applicable in the left bank at SEG4); and $tfishing_i$ is the time spent fishing. For visitors who travelled by car and accompanied, the TE_{ijCar} was divided by 2 because they were expected to share the costs.

Time costs (tC_{ij}) for each visitor and segment were calculated as:

$$tC_{ij} = t_{ij} \times tC_{mean} \quad (10)$$

where t_{ij} is the time spend travelling from the origin to the destination (*j*) by each visitor; and tC_{mean} is a constant that indicates the monetary value of the time spend travelling (€ min^{-1}), calculated as:

$$tC_{mean} = VTT \times {}^{I_{ind}}/_{wh} \times {}^{1}/_{60} \quad (11)$$

where I_{ind} is the mean available income per individual in the sample (=10,920 € year^{-1}); wh is the average annual working hours (=2080 h); and VTT is the average value of travel time per income, which following Fezzi *et al.* (2014) was considered equal to $3/4$.

2.2.3. Site-specific variables

The RUM assumes that site-specific attributes influence individual´s choices and should be included in the model. Recreational fishing is considered to be influenced by fishers characteristics (Abernethy *et al.*, 2007), by the infrastructures around fishing sites (Griffiths *et al.*, 2017), by environmental conditions (Hampton and Lackey 1976) and by the possibility of catching fish (Fedler and Ditton, 1986; Arlinghaus, 2006). These variables can potentially determine the recreational experience and consequently, fisher´s satisfaction with the activity (Hunt, 2005; Arlinghaus *et al.*, 2014, 2017), ultimately influencing the fishers´ site-choice and the number of trips to it. Considering the effect of catch and non-catch variables to the overall recreational fishing experience, four site-specific variables were selected to be included in the RUM (Table E1).

***Table E1** – Site specific variables considered to be introduced in the Random Utility Model. SEG: Segment.*

Variable	Description	SEG1	SEG2	SEG3	SEG4	SEG5
Fish	The ecological status in each segment was estimated using the data from Borja *et al.* (2017).	High	High	Good	Good	Moderate
Water access	The number of metres available to fish from shore, calculated in Chapter C.	1500	3500	1755	1020	450
Car park facilities	1= if there are car park facilities close to the fishing spots and 0=if there are not car park facilities or if facilities are shared with other groups such as residents.	1	1	0	0	0
Aquatic conflicts	1= If there is conflict with aquatic activities such as fishing boats, aquatic sports, etc. and 0=No conflict	1	1	1	0	0

The *Fish* variable is qualitative and defined considering the AZTI's Fish Index (AFI) values (Uriarte and Borja, 2009) measured between 2007 and 2017. From these measurements, segments were differentiated according to three categories: "high" ecological status, for the two segments in the outer Nerbioi, "good" in the SEG3 and SEG4, and "moderate" for the innermost SEG5 (Table E1).

Facilities in the recreational site could affect the number of trips taken by fishers. Therefore, two indicators were selected to be included in the RUM: (i) *water access*, defined as the shoreline metres available to practice the activity; and (ii) *car park facilities*, a dummy variable indicating the availability of car park facilities. Finally, to represent the possible conflicts with other activities that might have a negative effect on the recreational fishing activity, an additional dummy variable was defined, *aqua conflict*, which represents the conflict that might arose when the space is shared with other aquatic activities (e.g. recreational sports, maritime transport) (Table E1). The values of *car park facilities* and *aqua conflict* for each SEG were based on recreational fishers´ comments when carrying out the recreational fishing survey explained in Chapter B.

2.3. Future scenarios

The RUM coefficients were used to calculate the future welfare changes in recreational fishing benefits, which might occur if environmental conditions or accessibility change.

Seven future scenarios were defined considering the site-specific variables included in the final RUM and based on (i) plausible changes in the estuarine environmental conditions or (ii) the disappearance of certain SEGs as fishing sites (Table E3).

Scenarios SC1 and SC2 simulate extreme changes, based on the disappearance of recreational fishing from the outer Nerbioi. The SC1 simulated a fishing ban in SEG1, while SC2 simulated a ban in SEG1 and SEG2. These scenarios could only happen if the competition between recreational fishing and other activities (e.g. maritime transport, professional fishing, cruises) lead managers to ban the recreational fishing from the outer estuary.

In SC3 and SC4, improvement/worsening of environmental conditions were simulated for the whole estuary. The improvement of environmental conditions (SC3) could be achieved if a coastal submarine outfall, which would divert the WWTP inputs to the open sea, is built (Chapter C). Currently, the WWTP outputs are discharged to SEG3, negatively affecting the environmental conditions in the estuary. In SC4, the opposite situation, general worsening in environmental conditions, was simulated. This scenario could be related with future accidental failures of the WWTP, intense dredging works, etc. (Chapter C). Although this is unlikely to occur, this scenario gives an idea of how much welfare has been gained due to the improvement after the ecological restoration of the estuary.

In SC5 and SC6, the loss of accessible shoreline in the most popular SEGs, SEG1 and SEG2 (see Chapter B), were simulated. In SEG2, a recreational port has recently been expanded to allow cruise mooring in an area that is intensively used by recreational fishers, making the coexistence of the two activities difficult. In SEG1, the most popular recreational fishing site is a small port located on the left bank of the estuary, where the competition with other activities (mainly maritime transport) and the presence of professional and recreational boats is high. Therefore, the disappearance of shoreline in SEG2 (SC5) or a combined shoreline loss in SEG1 and SEG2 (SC6) were considered plausible scenarios. The SC7 is a combination of the previous SC3 (improvement of environmental condition) and SC6 (loss of shoreline in SEG1 and SEG2).

Following Parsons (2003), the change on welfare due to the disappearance of a fishing sites (ΔW_l), was calculated based on the equation for the maximum expected trip utility (eq. 4 in section 2.2.1.):

$$\Delta W_l = \frac{\left[\ln \sum_{j-1}^{i} exp(\beta_{tc}TC_j + \beta_z Z_j) - \ln \sum_{j}^{i} exp(\beta_{tc}TC_j + \beta_Z Z_j)\right]}{-\beta_{tc}} \tag{12}$$

where the difference between the maximum expected utilities with (j-1) and without (j) the disappearance of one site are divided by the travel cost coefficient. Change in welfare was again calculated per choice occasion (i.e. trip).

The change on welfare per choice occasion after changes in estuarine conditions ΔW_q was calculated as:

$$\Delta W_q = \frac{\left[\ln \sum_{j}^{i} exp\left(\beta_{tc}TC_j + \beta_z Z_j^*\right) - \ln \sum_{j}^{i} exp(\beta_{tc}TC_j + \beta_z Z_j)\right]}{-\beta_{tc}} \tag{13}$$

where Z_j^* captures the quality change in the variable Z on site j.

A mean value per trip was estimated as the mean value of ΔW_l or ΔW_q for the sample. The seasonal value per fisher and for the estuary were calculated following equations 6 and 7 for each change scenario.

3. Results

3.1. Characteristics of the sample

A total of 95 out of the 146 questionnaires obtained were used for defining the RUM. The rest were discarded due to: (i) respondents answered the questionnaire on a day when they did not fish inside Nerbioi, not providing information on transport (n=29); or (ii) the information regarding fishing days in each SEG was incomplete (n=22). The demographical characteristics of the sample are resumed in the Appendix E Table 1.

3.2. Valuation of recreational fishing benefits

Two out of the four site-specific variables were included in the RUM: *fish* and *water access*. *Car park facilities* and *aquatic conflicts* were tested but also discarded as their contribution to the model was negligible.

In the selected RUM (Table E2), the travel cost estimate was negative and significant, meaning that the likelihood of choosing a specific site for fishing decreases as travel costs increase. The *fish* estimates are positive, meaning the lower the fish quality, the lower the recreational benefit that recreational fishers obtain from the estuary. The *water access* variable was positive, meaning that utility increases as the number of metres available for fishing increases.

Table E2 *- Coefficients of the Random Utility Model in the Nerbioi.*

	Coefficient	**Std. Error**	**z-value**	**Pr(>|z|)**
Travel Cost	-0.184	0.005	-36.732	**<0.0001**
Fish "good"	1.751	0.071	24.58	**<0.0001**
Fish "high"	2.272	0.078	29.082	**<0.0001**
Water access (m)	$3 \cdot 10^{-3}$	$1 \cdot 10^{-5}$	21.066	**<0.0001**
log-Likelihood	-14,762			

The mean maximum expected utility per trip was estimated at 14.97 € trip^{-1} (sd=3.93). Considering the mean number of trips that each fisher makes to Nerbioi, the seasonal utility per fisher was estimated at 449 € year^{-1}, while the aggregated value for the entire recreational fishers´ community was 1.12 million € year^{-1}. The marginal WTP was 9.53 € trip^{-1} for *fish* in "good" status with the higher value corresponding to *fish* in "high" condition (12.37 € trip^{-1}). The *water access* variable affects to each trip in a positive way, 0.1 € trip^{-1} per 100 metres (0.00 1€ m^{-1}).

3.3. Future scenarios

The disappearance of recreational fishing sites from Nerbioi, simulated in scenarios SC1 and SC2 (complete disappearance of SEG1 and SEG1+SEG2, respectively) resulted in recreational fishing welfare loss with respect to the baseline, especially high for SC2 (42.4%).

Changes in estuarine conditions were simulated by modifying the values of the variables *fish* and *water access* in the RUM (Table E3). The SC3 corresponded to an improvement scenario, where *fish* was upgraded to "high" and resulted in a welfare increase of 11.5%. The worst scenario was registered in SC4, where *fish* was worsened to “moderate”, leading to a welfare loss of 71%. The reduction of the variable *water access* (SC5: loss of 1000m in SEG2 and SC6: additional loss of 700m in SEG1) had a moderate negative impact, with the lowest welfare change from the seven simulations.

All in all, the effect of change in *fish* was more intense than that observed after change in *water access*. Indeed, when changes in both variables were combined (SC7), the positive effect of fish improvement was able to compensate the shoreline loss, resulting in a final welfare gain of 7.5%.

Table E3 – *Welfare change for seven scenarios. In SC1 & SC2 the complete ban of fishing in some sites (SEG) was simulated. In SC3-SC7 changes in fish and water access variables were simulated. Data in italic indicates welfare change values. Key: “Change”, gain or loss in the aggregated seasonal value; “Absolute”, the aggregate seasonal value for each scenario and estimated by applying to the baseline aggregate seasonal value (1.12 million € year^{-1}) the value indicated in “Change”.*

Scenario	Description	€ trip^{-1} (mean)	€ season^{-1} (fisher)	€ season^{-1} (fishers´ community)	
				Change	Absolute
Baseline	Current situation	14.98	449.4		1,123,426
Change in access					
SC1	Fishing is forbidden in SEG1	*-1.28*	*-38.4*	*-95,915*	1,027,511
SC2	Fishing is forbidden in SEG1 and SEG2	*-6.35*	*-190.5*	*-476,220*	647,206
Change in quality					
SC3	*Fish* improves to “high” in all SEG	*+1.73*	*+51.8*	*+129,571*	1,252,997
SC4	*Fish* decreases to “moderate” in all SEG	*-10.64*	*-319.2*	*-797,909*	325,517
SC5	Shoreline reduction: 1000m (35%) in SEG2 right bank	*-0.61*	*-18.3*	*-45,645*	1,077,781
SC6	Shoreline reduction: 1000m (35%) in SEG2 right bank & 700m (47%) in SEG1 left bank	*-0.82*	*-24.6*	*-61,549*	1,061,877
SC7	Combination of SC3 & SC6	*+1.12*	*+33.5*	*+83,676*	1,207,102

4. Discussion

The probability of visiting the different fishing sites in the Nerbioi is determined by the costs and distances to reach them, the environmental conditions (i.e. fish conditions) and the length of accessible shoreline. The dependence of the utility with the different characteristics is consistent with previous economic valuation studies performed in other aquatic environments (Bateman *et al.*, 2016). Indeed, spatial restrictions, crowding, fish catches and environmental quality are some of the most important variables considered to influence recreational fishers´ satisfaction (Arlinghaus, 2005; Griffiths *et al.*, 2017). Two of those four variables were included in the model (i.e. spatial restrictions and environmental quality), while crowding and fish catches could not be added due to lack of data.

The environmental improvement of the Nerbioi estuary in the last decades (Borja *et al.*, 2010a; Cajaraville *et al.*, 2016) is responsible of the current good status of fish (Uriarte and Borja, 2009). Also, the RUM highlighted the importance of fish status in the fishing utility associated with the SEGs, as the better the fish status in a specific SEG, the greater the probability of a fisher visiting it. Therefore, the current value of recreational fishing (estimated at 449 € year^{-1} fisher^{-1} and in 1.12million € year^{-1} for recreational fishers´ community) is a direct consequence of the management measures adopted to improve the estuarine sanitary and ecological conditions. Environmental changes can encourage recreational fishers to change their behaviour (Fulford *et al.*, 2016), as reported for Nerbioi (Chapter B), and this additional social benefits can be monetarily assessed.

The analysis of future scenarios suggested that the environmental conditions (i.e. fish status) impact the recreational fishing activity. Indeed, the highest welfare gain and loss were obtained in the scenarios where improvement and worsening of *fish* status were simulated. The presence of fish and the possibility of catching them is essential for fishers when deciding where to fish (Fedler and Ditton, 1986; Arlinghaus, 2006). The combination of shoreline loss with improvement on fish status resulted in a positive effect on welfare, which indicates that environmental conditions (in terms of fish and catches) are more important than shoreline accessibility on fishing-site choice.

Changes in accessible shoreline have a lower effect on recreational fishing than changes in environmental conditions, as reflected in the scenarios where the changes in shoreline were analysed alone. The incidence on welfare was relatively lower for shoreline loss than for changes in fish status. The low number of accessible fishing spots has been pointed out as an important limitation for recreational fishing in urban areas (Arlinghaus and Mehner, 2004); therefore, future management measures affecting negatively to accessibility should be carefully analysed. Indeed, the extension of the industrial port in the left bank at SEG1 worsened the accessibility in the outer Nerbioi in the last decades. According to the questionnaires collected in Chapter B, recreational fishing was intensively practiced in this part of the estuary before the port extension, but the welfare loss could not be estimated due to the lack of historical data on the recreational activity in Nerbioi. Even with the reduction of shoreline, the competition with other activities in outer Nerbioi, and the improvement of the environmental conditions in the inner estuary, fishers still prefer to fish in the outer Nerbioi (Chapter B). Therefore, the monetary value of recreational fishing in the estuary is highly dependent on the outer area. However, if other maritime activities continue to compete with recreational fishing in the outer Nerbioi and the environmental conditions continue to improve in the inner part, a change in recreational fishers´ preferences and behaviour might occur.

The functional form of the RUM selected resulted in certain limitations and therefore, the estimated value should be used with caution. The relatively low number of surveys and the high number of trips taken by each respondent led to the adoption of a model where each trip is a single choice occasion, independent of the previous trips taken by the same individual. Considering that the own recreational experience will not influence future trips is an important assumption (Parsons and Massey, 2003). Also, the model only uses site-specific variables as explanatory variables, ignoring the characteristics of the decision-maker (Paltriguera *et al.*, 2018). The number of responses did not allow the application of the more precise mixed conditional model, which introduces decision-makers characteristics as dependent variable and allows the correlation between the different aspects of the utility (Paltriguera *et al.*, 2018).

The data used for aggregation was based on Ruiz *et al.* (2014) and Chapter C, which estimated the fisher community in Nerbioi in ~2,500 fishers, with 30 fishing trips year^{-1} in mean. This is a rough approximation to the recreational fishers´ community, and future studies able to differentiate between active and inactive recreational fishers, as well as preferred fishing areas, would improve the accuracy of the aggregated value.

This study suggests that recreational fishing in Nerbioi is an important economic activity, which adds to its social importance explored in Chapter B. Furthermore, this activity is only one of the multiple activities that could have benefited from water improvement, and that the positive effect could be even higher for the others. Viana *et al.* (2017), who studied different recreational activities in a marine sanctuary, found that the group of recreational users that place the less relative importance to environmental quality were indeed recreational fishers.

The monetary valuation of recreational fishing complements the results of Chapter B and C, which analysed the activity for its social importance and environmental dependency. These studies offer complementary information, and their combination could be helpful in advancing towards an integrative approach for ecosystem services valuation and for better understanding and managing of these social-ecological systems (Outeiro *et al.*, 2017).

The monetary value of recreational fishing estimated in this study adds to a previous study that estimated the recreational use value of the estuarine beaches (Chapter D). The aggregated use value of these two activities is estimated in more than 4.6 million € year^{-1}, which is an important amount able to cover partially the costs of WWTP maintenance, estimated in 23.7 million € year^{-1}.

Due to the econometric methodology followed in this study and the one performed in beaches (Chapter D), the benefits provided in Nerbioi have only been partially valued. First, because the travel cost methodology can only estimate the use values of the activities, but this environment can also provide non-use values. To calculate non-use benefits, the current information could be complemented with a stated preference method exercise, asking direct questions to identify both use and non-use values. Also, the economic valuation is considered partial because, recreational fishing and beach recreation are only two of the multiple recreational activities happening in Nerbioi, activities that have not been valued yet, and that will increase the economic value of the ecosystem services provided by this restored ecosystem.

The valuation of cultural ecosystem services and their nonmarket benefits, such as recreational fishing, provide useful information to managers, who could incorporate the data in analysis for policy decisions (Viana *et al.*, 2017). Nerbioi estuary, being in a highly populated area, offers to its inhabitants many recreational opportunities, and ecological restoration has increased those opportunities. Indeed, increasing recreational outdoor opportunities in urban areas can have a greater impact on welfare than in rural areas, which could be related with the scarce number of similar recreational alternatives (Bateman *et al.*, 2016).

5. Conclusion

Economic valuation of changes in recreational activities in restored ecosystems can be performed specifying multi-site travel cost RUMs. This revealed preference technique allows the incorporation of the environmental conditions that changed after ecosystem restoration and that potentially influenced the recreational activity. The economic valuation of restored ecosystems provides valuable information for managers in two ways: first, because it allows the valuation of the welfare change after restoration; and second, because the built model can be used to simulate future conditions and analyse the expected gains or losses in welfare.

GENERAL DISCUSSION

General discussion

It has been discussed elsewhere if environmental restoration measures, as human pressures removal, could have positive effects in key ecological components for the provisioning of ecosystem services, and consequently increase human well-being (Aronson *et al.*, 2010; Cooper *et al.*, 2013; De Groot *et al.*, 2013; Bayraktarov *et al.*, 2016). This thesis focused in determining if the reduction of pollution loads, through the introduction of wastewater treatment and the removal of polluting industries in the Nerbioi estuary, resulted in an increase of cultural ecosystem services and human benefits; focusing more precisely in two recreational activities: recreational fishing and beach recreation. Changes in these two recreational activities were analysed from a triple and complementary perspective: environmental, social and economic. The environmental perspective (for which more knowledge was available) analysed the changes in the key biotic and abiotic components that are likely to determine the potential of the ecosystem to provide services (Chapters A and B). The social perspective analysed recreationalists´ perceptions and behaviour towards the quality of the estuary after restoration, which was never studied before (Chapters A and B). For the economic perspective, monetary valuation of recreational fishing and beach recreation was performed and compared with investments needed to restore the estuary; also, the first study of this kind (Chapters D and E). Furthermore, this thesis took a step forward and combined the environmental and social perspectives into a social-ecological system dynamic model. This model demonstrated the strong links and interrelation between environmental and social factors in ecosystem services provisioning, which could be especially useful to envisage the effects of future scenarios and help managers and policy-makers to make informed decisions (Chapter C).

1. The environmental perspective

Being ecosystem services the benefits provided by ecosystems that contribute to human well-being (Millennium Ecosystem Assessment, 2005a), it is important to establish the **links between the specific components of natural capital that make** those **human benefits possible**. When performing assessments of ecosystem services, the causal contributions of specific biotic and abiotic components (as part of the natural capital) to the provision of ecosystem services must be determined to better understand the relations between ecosystem conditions, flow of ecosystem services and human well-being (Jax, 2005; Carpenter *et al.*, 2009; Costanza *et al.*, 2017; Teixeira *et al.*, 2019).

In the Nerbioi estuary, it is well-known that **biophysical conditions improved** after 1990 with the implementation of restoration measures (Cajaraville *et al.*, 2016). The most important change was the reduction of wastewater loads (considered as human "Pressures" in the DAPSI(W)R(M) framework, see the Introduction of this thesis), which led to the decrease of ammonium and organic matter concentrations in water, and consequently, to an increase in the oxygen saturation in the water column (all of them considered as "State Changes" in that framework). Ultimately, these changes resulted in an increase of biodiversity in the estuary (Borja *et al.*, 2010a; Pascual *et al.*, 2012), which had been "Impacted" in the past. The two recreational activities studied, recreational fishing and beach recreation, depend on water conditions (and biodiversity in the case of fishing); a minimum quality over certain biotic and abiotic components is required in order to perform any of them. Both recreational activities were considered as part of the human "Welfare" in the DAPSI(W)R(M) framework (Figure 6).

The wastewater treatment ("Response" and management "Measures" in the framework) decreased the microbial concentration of the loads into the estuary, with positive consequences for **beach recreation**. Nowadays, the waters in the three beaches of the Nerbioi estuary comply with the requirements of European legislation on bathing waters, which focuses on microbial pollution (Chapter A). Also, the decrease of discharges of untreated wastewaters was the main reason for an increase in water clarity, which is known to affect judgment of users on water cleanliness (Peng and Oleson, 2017). Therefore, the two parameters selected to analyse the biophysical conditions of beach recreation (i.e. microbial concentration and water transparency), improved after the restoration measures were adopted (Chapter A).

The biophysical conditions required for practicing **recreational fishing** were considered as a combination of water quality conditions and fish conditions (Chapter B). Water quality was assessed through ammonium concentration and oxygen saturation, while fish conditions were assessed with demersal fish abundance and richness data. Indeed, the presence of fish and the possibility of catching them is considered a pre-requisite for the development of the activity (Fedler and Ditton, 1986; Arlinghaus, 2006). It is well-known that fish conditions only recover after improvement of oxygen saturation in systems subject to high urban and industrial discharge loads (Uriarte and Borja, 2009). Hence, the analysis of the biophysical conditions indicated an improvement trend in Nerbioi, after the restoration measures were adopted (Chapter B).

The changes registered in the selected biophysical conditions are indicative of better environmental conditions suitable for recreational fishing and beach recreation. This thesis focused in these two specific recreational activities but the improvements in the environmental conditions in the Nerbioi estuary are likely to have had positive effects on other human benefits through the improvements in the conditions required to perform further activities. All in all, investments done to improve the ecological status of an ecosystem (e.g. implementation of wastewater treatment) can improve specific biophysical conditions required to perform human activities (e.g. recreation) and can potentially increase social and economic value of the system (Figure 6).

2. The social perspective

The changes in the biophysical conditions, as described in Chapters A and B, increased the capacity of the Nerbioi estuary to provide recreational ecosystem services, i.e. an improvement of ecosystem services from the **supply-side.** The supply-side of the ecosystem services is defined as “the potential and capacity of an ecosystem to supply services, whether or not these are used” (Teixeira *et al.*, 2019).

In recreational ecosystem services, the supply-side is not only determined by the biophysical conditions, but also by **supporting elements** (Jenkins and Pigram, 2006; Kulczyk *et al.*, 2018), such as accessibility, facilities or infrastructure (Villamagna *et al.*, 2013). These supporting elements are part of the built capital that is needed, together with social, human and natural capital, to produce human benefits (Costanza *et al.*, 2014). Supporting elements for recreational ecosystem services can influence user´s behaviour and they need to be present in order to enable recreation (Kulczyk *et al.*, 2018). In this thesis, the supply-side analysis mainly focused on biophysical conditions, and supporting elements were treated as complementary, but secondary information (Chapters A and B). The main reason is that the thesis focused on how the provision of ecosystem services can be affected by environmental restoration measures, which create changes in the biophysical conditions (i.e. how “Responses” in the form of management “Measures” affect the whole DAPSI(W)R(M) framework, recovering the ecosystem services and human well-being).

Still, the supporting elements were not completely ignored, as possible changes in them could cause changes in the supply-side. In the Nerbioi estuary there have been some changes in supporting elements (e.g. the extension of the commercial port in the outer Nerbioi has limited the access for recreational fishers). However, changes in these elements can be considered minor in comparison to the changes registered in the biophysical conditions. At least, most of the area was accessible and infrastructures and facilities required for the practice of both recreational fishing and beach recreation were present in the estuary: (i) the three beaches inside the estuary were accessible and the waters of all of them were declared as bathing-waters, according to legislation (AZTI, 2011); and (ii) recreational fishing, although not having specific infrastructures for the activity, could be practiced in the outer and inner estuary (with certain limitations imposed by the presence of other activities, such as port facilities).

The assessment of recreational ecosystem services from the supply-side (i.e. biophysical conditions and supporting elements) equals to analysing the potential of the ecosystem to provide services (Hernández-Morcillo *et al.*, 2013; Kulczyk *et al.*, 2018). However, to use the supply of services as direct indicator of ecosystem services is not correct; supply does not necessarily translate into social benefits and it does not necessarily reflect what people value (Boyd *et al.*, 2016; Olander *et al.*, 2018). To check if restoration actions translate into social benefits within the DAPSI(W)R(M) framework, equals to checking if the adoption of “Response Measures” led to positive consequences for “Welfare” (Figure 6).

If ecosystem services are the benefits that humans obtain from ecosystems (Costanza *et al.*, 2017), the service provisioning, the output in the form of human benefits, and the links between them should be studied and characterized in order to perform a complete ecosystem services assessment; i.e. the assessment should **combine the study of the supply-side and the demand-side** (Syrbe and Walz, 2012; Palomo *et al.*, 2013; Villamagna *et al.*, 2013).

In this thesis, it has been hypothesized that changes in estuarine biophysical conditions could have caused changes on the **demand-side** of recreational services and consequently, on human well-being. In the ecosystem services literature, there are varying ideas about what demand-side represents and the most appropriate indicators to assess it (Wolff *et al.*, 2015). Some authors define service demand as the current use or consumption (Burkhard *et al.*, 2012), while some others argue that demand assessment should inform about the amount of a service required or desired (Villamagna *et al.*, 2013). In this thesis, the definition by Kulczyk *et al.* (2018), was adopted, who argued that the demand-side of recreational ecosystem services should include recreationalists and their willingness to undertake nature-based activities.

In Nerbioi estuary, the data on **current recreational use** of the area was scarce, except for the terrestrial realm (Casado-Arzuaga *et al.*, 2013, 2014). Focusing on the two recreational activities studied in this thesis, the interest was placed in the current number of recreationalists performing the two activities, as well as in comparing the current use with the one in the past (i.e. the change in recreational use after adoption of restoration measures). For beach recreation, the regional government has been collecting data on the number of beach visitors following a standardized protocol only since 2013 (Chapters A and D); the mean number of visits to Nerbioi beaches is higher than 500,000 per season. As the data on beach visitors were only available since 2013 and for summer, it was possible to approximate a current recreational use of the beaches in this estuary, but definitively not an appropriate analysis of the changes occurred in the service demand after restoration measures (i.e. if the number of beach visitors changed after the adoption of the restoration measures).

For recreational fishing, although the exact number of recreational fishers who currently fish in the estuary is unknown; in this thesis, an estimation of 2,500 was made based on the number of active fishing licenses (Chapters B and C) and previous studies on recreational fishing in the entire Basque Country (Ruiz *et al.*, 2014). Regarding the possible change in recreational fishing demand after restoration, the number of active recreational fishing licences in the estuarine villages for the period 1999-2015 suggest a positive trend of the activity (Chapter B, Figure B4). However, these data are a rough approximation to the number of active fishers, as living around does not necessarily imply practicing the activity in the area. Furthermore, being the licenses issued for a total of five years, some people may hold an active fishing license but not practice the activity any more. Due to the aforementioned data constraints, in this thesis (Chapters A and B) the analysis of the demand-side was performed: (i) capturing current recreationalists´ behaviours and perceptions using surveys; and (ii) exploring the likely changes on behaviour and perceptions after restoration, by including in the surveys specific question aimed at experienced users (i.e. visitors who have been practicing recreational activities in the estuary for many years).

The analysis of the **current behaviour of beach visitors** revealed that the possibility of bathing was one of their main motivations to go to the beach. Indeed, most of them indicated that they practiced aquatic activities in these beaches, with significant differences between beaches; the most internal beach had a significant lower percentage of users who practiced aquatic activities (Chapter A). This result goes in line with the trend found for biophysical conditions, as the most internal beach was and still is the beach with the worst conditions (i.e. higher microbial pollution and lower water transparency). Also, these findings fit with previous studies in other locations, in which there is a clear relationship between the use of beaches and the quality of them (Kreitler *et al.*, 2013; Aragonés *et al.*, 2016; González and Holtmann-Ahumada, 2017).

The questionnaire distributed among **recreational fishers who currently fish** in the estuary, showed their preference to fish in the outer estuary, where the water quality and fish conditions were and still are better than in the inner estuary. Fishers´ preference for the outer estuary over the inner estuary, together with the importance that they placed to water quality parameters as determinants of fishing enjoyment

(Chapter B), suggests that fishers considered the biophysical conditions when they decide where to fish. Again, this finding is similar to those reported in other locations around the world (Fedler and Ditton, 2000; Arlinghaus *et al.*, 2002; Vesterinen *et al.*, 2010; Fulford *et al.*, 2016); however, some controversy still exist with some studies reporting just the opposite (Ziv *et al.*, 2016).

In order to relate the changes in the supply-side with changes on the demand-side, it is necessary to analyse if users have changed their behaviour and/or perceptions towards the recreational activities. The analysis of **changes in behaviour and perceptions** is crucial to link restoration measures with changes in provisioning of ecosystem services and human well-being, within the DAPSI(W)R(M) framework. To establish whether this link existed in Nerbioi, specific questions were included in the survey for users who have been fishing or bathing in the estuary for long enough to have experienced the changes in the biophysical conditions.

Recreational users can modified their behaviour as a response to changes in environmental conditions, such as water quality (Roca and Villares, 2008; Fulford *et al.*, 2016). In Nerbioi, the analysis of **changes in recreational fisher's behaviour** suggested that fishers progressively entered to the inner estuary, responding to the improvements in water quality, fish richness and fish abundance. This change in behaviour matched the environmental changes registered in water quality and ichthyofauna (Chapter B). The **changes in beach recreationalists´ behaviour** were analysed indirectly, asking respondents how probable was that they would not come back if water quality was to worsen. Results revealed that most of them would not come back if water quality worsens; and together with the importance placed to aquatic activities as a motivational factor to visit beaches, it was concluded that water quality improvement had been important to the development of the beach recreation (Chapter A).

Beach visitors and recreational fishers **perceived an improvement in water quality,** which goes in line with the ecological improvements in the estuary. The predominant perception of a positive change over water quality was found among all recreationalists in Nerbioi. Furthermore, they associated the improvements in recreational fishing and in bathing waters conditions to the adoption of a specific management measure, the implementation of the WWTP (corresponding to “Response” and management “Measures” within the DAPSI(W)R(M) framework), meaning that “State changes”, forced by a legal requirement, led to a change in social perceptions (Chapters A and B).

Variables such as age or education level have been described as determinants of public perceptions towards restoration projects (Pueyo-Ros *et al.*, 2018). In Nerbioi, the most important socio-economic characteristic influencing perceptions was **experience,** i.e. number of years that recreational fishers and beach visitors have been practicing the recreational activities. Indeed, experience was found to determine the **accuracy between most of the recorded environmental changes and perceived changes,** as the most experienced visitors were able to perceive more accurately changes in water quality (among recreational fishers and beach recreationalists) and changes in the number of users (among recreational fishers). However, the effect of experience in recreational fishers´ perceptions for fish variables was the opposite, as the more experienced the user, the more inconsistent its perception was with recorded changes in fish conditions.

Apart from the perceived worsening in fish parameters among recreational fishers (especially among the most experienced ones), also among beach recreationalists there was an important percentage of them who did not practice aquatic activities due to the negative perception they still had on water quality in Nerbioi beaches. All these negative perceptions that did not match with data on environmental conditions suggest that past negative perception over environmental conditions are difficult to overcome. Furthermore, punctual pollution events (e.g. in 2018, Nerbioi beaches registered peaks of microbial pollution after heavy rains) could be negatively affecting the perception of current users. The inconsistency between certain perceptions and recorded environmental changes could be due to different reasons (see Discussion in Chapter B), among others, failed communication actions and lack of adequate environmental education campaigns. The lack of **public awareness** regarding certain aspects of restoration could be used by local managers when defining the focus and target groups for new awareness campaigns.

Socio-economic characteristics of users such as cultural origin or social status can influence recreational behaviour and activity-choice (Kulczyk *et al.*, 2018). More generally, social characteristics are known to influence people´s perceptions over ecosystem services (Martín-López *et al.*, 2012) and over the value they place to them (Lau *et al.*, 2018). Among recreationalists in Nerbioi, social characteristics, knowledge and experience practicing the activity were found to influence people´s choices and perceptions. Also, differences were found in the **socio-economic profile** of beach users and recreational fishers in terms of gender (recreational fishers were mainly men while beach visitors were predominantly women), employment status (recreational fishers were mainly inactive and beach visitors mainly active) and education (recreational fishers were less educated than beach visitors). On the other hand, both recreationalists groups were mainly middle-aged locals. The high percentage of locals among both recreational activities is an interesting data, as they have been described as a social group that value the restoration projects less than other visitors (Pueyo-Ros *et al.*, 2018). Differences between users´ profiles were not only found between the different activities (i.e. recreational fishers and beach visitors), but also between different users in the same group.

The characterization of the current demand for recreational services (e.g. user´s socio-economic profile, recreational site preferences) provides important information to advance towards ecosystem services research in local areas such as Nerbioi catchment. Indeed, the social characteristics captured trough questionnaires provided valuable data on users´ preferences and perceptions that complemented the recorded environmental data. These findings can be useful for local managers, who could use this information to focus future management actions to specific target groups. In Nerbioi, the analysis of the social perspective led to the conclusion that certain **mismatch between services supply and demand** exists, as the favourite beaches and sites for fishing were not always the places with the best biophysical conditions. The spatial mismatch between supply and demand areas has been previously reported (Palomo *et al.*, 2013; Villamagna *et al.*, 2014a; Ziv *et al.*, 2016); the results in Nerbioi reinforce the idea that apart from biophysical conditions, supporting elements are an important part of the supply-side and that they might be decisive for users´ final choice (i.e. they influence demand-side). Also, the results highlighted that socio-economic characteristics of the beneficiaries shaped the demand-side of ecosystem services.

The information collected from the ecological and social perspectives was used to build a system dynamics model for recreational fishing in Chapter C, a model that can be useful to decide which are the most appropriate future management decisions in Nerbioi catchment.

3. Linking and modelling supply and demand of ecosystem services

Once the elements that are part of the supply and demand sides have been described, it is necessary to assess the **flow** between both sides, i.e. the delivery of ecosystem services (Villamagna *et al.*, 2013; Kulczyk *et al.*, 2018). However, the links between the different elements (i.e. natural, human, social and built capital) that constitute the supply and demand sides of ecosystem services and contribute to human well-being are not still clear (Costanza *et al.*, 2017). This knowledge gap is the main reason for the lack of integration of ecosystem services in planning and policy and should be considered in the DAPSI(W)R(M) framework, when management measures (R(M)) are needed to recover services and increase human well-being. Ecosystem services are underrepresented in conservation planning, leading to the adoption of management decisions that rarely consider effects over those services (De Groot *et al.*, 2010).

The inclusion of ecosystem services in policy and management will help securing their sustainable use. For this reason, ecosystem services research needs to advance towards approaches that are able to link environmental and social aspects of the ecosystem capacity, identify and quantify the current service demand and measure the current delivery of services (Villamagna *et al.*, 2014b). In other words, research needs to consider and study all the forms of capital (i.e. natural, human, social and built capital), together with their links and interactions, involved in the delivery of human benefits and influencing human well-being. These research advances could provide managers with appropriate information that they could use when planning future management actions (Villamagna *et al.*, 2014b).

In this thesis, in order to contribute to ecosystem services research gaps, a model for recreational fishing was designed (Chapter C). As commented before, recreational fishing is considered a social-ecological system (Arlinghaus *et al.*, 2017) and, as such, it is influenced by complex and dynamic social and environmental factors (Small *et al.*, 2017). Hence, SDM is considered an adequate modelling approach for representing these systems (Patterson *et al.*, 2004; Laniak *et al.*, 2013). Using a SDM tool and following a social-ecological systems approach, the model was designed including environmental and social drivers that together with their interactions were known to provide human benefits in the form of recreational fishing (Arlinghaus *et al.*, 2017). Thus, the model was fed with pollution inputs from the WWTP and the Nerbioi tributaries, that nowadays constitute the most important pressure for the ecological status of the estuary. The ecological status was represented with physicochemical parameters (i.e. dissolved oxygen, ammonium concentration), and biological elements (i.e. fish abundance and richness). The relationships between the different biophysical elements were established with the environmental data collected in the estuary for the last 30 years. The biophysical conditions constituted the ecological sub-system of the SDM and represented the natural capital of the ecosystem needed to provide recreational fishing benefits.

The ecological sub-system was linked to the social sub-system using fish abundance and fish richness parameters, as the presence of fish and the possibility of catching them is essential for making the recreational fishing activity possible (Arlinghaus, 2006). The social sub-system was built with social data collected through the questionnaire in Chapter B and with available information on the recreational fishing activity in the Basque Country (Ruiz *et al.*, 2014). Recreational fishing, as a cultural ecosystem service, is considered to contribute to human well-being by providing **non-material benefits** to society (Small *et al.*, 2017), and this conditioned the indicators chosen for the representation of the service demand in the social sub-system.

Non-material benefits provided by recreational services are influenced by complex and dynamic social and environmental factors (Chan *et al.*, 2012; Small *et al.*, 2017). To adequately represent this characteristic in the model, the variables selected as key indicators of recreational fishing were the number of recreational fishers and overall satisfaction with the activity. The number of recreational fishers represents the current demand for the service (Kulczyk *et al.*, 2018). The current quality of the activity was measured with fishers´ overall satisfaction, which has been pointed out as an adequate indicator when working with recreational activities (Loomis and Paterson, 2014).

Studies that compare biophysical supply with social demand are scarce (Kulczyk *et al.*, 2018), and Chapter C contributes to increase knowledge in this regard. There is still not a full comprehension of all the elements, their interlinkages and their influence on recreational fishing (Fenichel *et al.*, 2013), but it becomes clear that managers need to have a wider scope when planning future actions, since environmental measures could affect recreational activities and *vice versa*. In addition, researchers should provide managers with scientific information and appropriate tools that are able to overcome uncertainties about the recreational activity. In this context, SDM is a useful tool for representing complex systems where the relations between components are dynamic and non-linear (Schmitt Olabisi *et al.*, 2010), even with the high levels of uncertainty that usually characterize ecosystem services assessments (Ainscough *et al.*, 2018).

Future scenarios were defined to run simulations that could forecast the effects of management alternatives and unexpected environmental changes on recreational fishing. The **simulations** run in the Nerbioi revealed that accidental failures, management measures and global climate change will change the ecological equilibrium of the estuary and affect the recreational fishing activity. The results of simulations in SDMs should be analysed in terms of the expected trends or behaviour of key indicators, rather than on absolute numeric changes. Still, SDM is a valuable tool to inform and raise attention of stakeholders over the expected changes that different management decisions may cause (Ghaffarzadegan *et al.*, 2010; Elsawah *et al.*, 2017). Being the Nerbioi an estuary with different interests from various stakeholders and requiring high levels of management, the results of Chapter C provided valuable information to local authorities for planning future management measures. Indeed, future management measures adopted in restored ecosystems should be taken considering that new benefits (and potential new beneficiaries) could appear as an output of the restoration project.

The model designed in Chapter C measured the benefits in non-monetary terms (i.e. number of recreational fishers, overall satisfaction) for recreational fishing. Unfortunately, the model representing the **flow between supply and demand for bathing waters and beach recreation** could not be elaborated due to the lack of appropriate information of water quality and an appropriate time lapse between samples. The concentration of microbial pollution is highly variable (with high levels of increase and decrease in hours) and highly dependent on sun radiation and rainfall (Aragonés *et al.*, 2016). As microbial sampling in bathing waters in Nerbioi was only performed during four months per year and with a regularity of one sample per week, the relation between water quality and users´ behaviour could not be established reliably. Therefore, the valuation of beach recreation was done performing an economic valuation (Chapter D). For recreational fishing, the analyses perfomed in Chapters B and C were complemented with an economic valuation (Chapter E).

4. The economic perspective

Monetary valuation can provide information about changes to welfare after the adoption of ecosystem management measures (Pascual *et al.*, 2010). Therefore, it could be especially relevant in restored ecosystems, where high investments are needed to remove pressures and/or to mitigate the impacts caused by human activities. Being able to assign a monetary value to the restoration outputs (in the form of improvements in ecosystem services and human well-being) could be used to inform managers, policy-makers and society in general about welfare changes after high economic investments (Figure 6).

Valuation of ecosystem services has been divided into three types of values: ecological, socio-cultural and economic (De Groot *et al.*, 2002). The economic value of ecosystem services that lack of a formal market (e.g. cultural ecosystem services) is commonly performed using revealed and stated preference approaches (Badura *et al.*, 2016). In this thesis, separate economic valuations for the two recreational activities in

Nerbioi were performed, based on revealed preference approaches, specifically travel cost methods, which are commonly used to value recreational uses of the environment (Parsons, 2003).

For the **monetary valuation of beach recreation**, single-site travel costs models were built for each of the three beaches located in Nerbioi (Chapter D). The results of the cost-benefit analysis, where restoration investment costs were compared with the benefits returned to society in the form of beach recreation, concluded that seasonal beach recreation benefits covered the annual beach maintenance costs. Future expected changes, such as inhabitant reduction in the region or increase in beach maintenance costs, would most probably not compromise the positive result of the cost-benefit analysis. Single-site travel cost is frequently used to value nature-based recreation (Voke *et al.*, 2013; Ezebilo, 2016; Alves *et al.*, 2017; Mayer and Woltering, 2018); however, applying single site approach to restored ecosystems such as Nerbioi estuary has important limitations, as recreational benefits cannot be associated to site characteristics or to environmental changes. The models in Chapter D treated each beach as the unique alternative taken by each visitor, as surveys did not include questions regarding potential trips to the other two beaches inside the estuary. Consequently, the benefit estimation in Chapter D gave independent monetary values of the three beaches, treating them as independent alternatives and not considering that future environmental changes could affect their value. Also, the adoption of a cost-benefit analysis focusing on a single activity and based on single users´ preferences in an area, where multiple activities and stakeholders exist, should be considered as a limited approach (Martino *et al.*, 2019) and results should be interpreted carefully.

The **monetary valuation of recreational fishing** was performed using a random utility travel cost model (Chapter E), which is considered a more advanced method than the single-site travel cost model approach and allows the consideration of environmental characteristics (Parsons, 2003). Indeed, environmental conditions are known to affect visitors behaviour and satisfaction with outdoor recreational activities (Pendleton *et al.*, 2001; Wilson *et al.*, 2005; Fulford *et al.*, 2016). It was possible to apply a **RUM** for recreational fishing in Nerbioi because surveys collected information on the number of trips that each visitor made to the different fishing sites in the estuary (i.e.

estuarine segments, Chapter E). The results of Chapter E revealed the high dependence of recreational fishing over environmental conditions, which was also reflected in the results of the future scenario simulations. Indeed, the most positive and most negative effects on welfare were obtained in the two scenarios where improvement and worsening of the fish status are simulated, respectively.

The aggregated monetary value of the two recreational activities was estimated in more than 4.6 million € year^{-1}, which covered part of the costs needed to maintain the water quality of the estuary (i.e. sewage system maintenance costs) estimated in 23.7 million € year^{-1}. Recreational fishing and beach recreation are only two of the multiple recreational activities happening in the estuary, and only some of the multiple ecosystem services that this ecosystem provides. Other ecosystem services have most likely benefited from the water quality improvement and therefore, also contribute to cover the water quality maintenance costs. Economic valuations provide local managers with measures of benefit gains after restoration and with expected welfare changes after future management measures.

Traditionally, there has been a bias among scientists and policy-makers towards favouring economic valuation (Gómez-Baggethun and Ruiz-Pérez, 2011) over the other two types of valuation. Consequently, value of ecosystem services has commonly been used as synonym of economic valuation (Costanza *et al.*, 1997), contributing to the disregard of the multiple values that ecosystem services have (Gómez-Baggethun *et al.*, 2014) and that are not easily captured through econometric tools. Economic valuation is a useful technique that provides valuable outputs for managers and policy makers (Turner *et al.*, 2010), but it should be adopted together with other types of valuation (Chan *et al.*, 2012) and clearly acknowledging the limitations that these techniques have (Pascual *et al.*, 2010).

5. Integrative approach in assessment of ecosystem services

The adoption of an integrated valuation approach for ecosystem services requires a combined analysis of all the ecosystem services components (Geijzendorffer *et al.*, 2015; Castillo-Eguskitza *et al.*, 2018), including factors related with the service user

(Hernández-Morcillo *et al.*, 2013). This could be necessary to adopt adequately the DAPSI(W)R(M) framework (Elliott *et al.*, 2017), since restoration in the form of "Response Measures" that remove "Pressures" from an ecosystem can generate positive effects on the ecosystem "Status" and positive "Impact" on biological components, contributing to ecosystem services flow and translating into human benefits or "Welfare" (Figure 6).

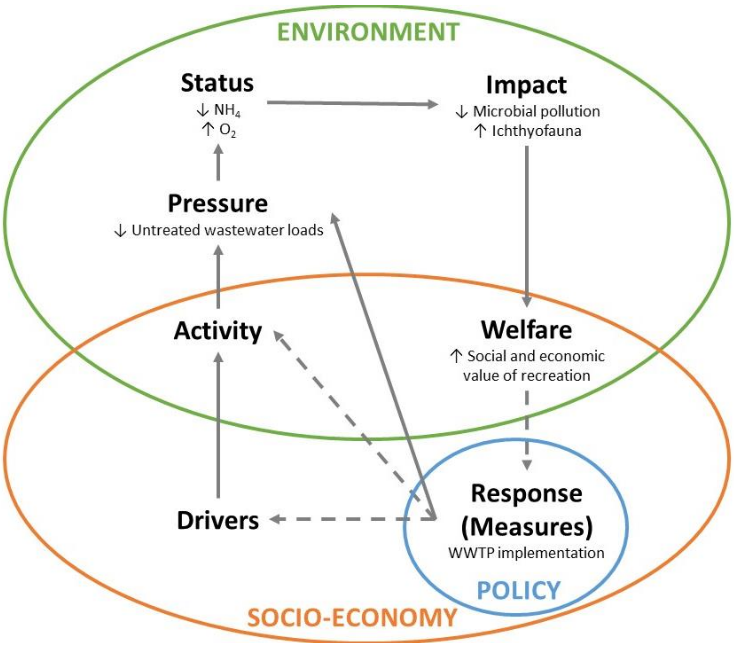


Figure 6 *– Nerbioi estuary restoration process explained with the DAPSI(W)R(M) framework. The socio-economic sphere contains the "Drivers", the environmental sphere contains "Pressures", "Status" and "Impacts". "Activity" and "Welfare" are part of both the socio-economic and environmental spheres, as complex links between environmental and social elements are needed to carry out activities and to obtain welfare (understood as human well-being). "Response" in the form of management "Measures" are adopted from the policy sphere, which is part of the socio-economic sphere. "Response (Measures)" can be adopted to change or remove "Drivers", "Activities" or "Pressures". In this figure, the links between "Response (Measures)" – "Drivers" and "Response (Measures)" – "Activity" are represented with dotted arrows because in the case of Nerbioi, "Response (Measures)" were adopted uniquely to remove "Pressures".*

In this thesis, the ecosystem services assessment after ecological restoration was performed focusing on two recreational activities. The activities were selected due to their potential dependency on water quality, a condition known to have significantly improved in the last 30 years in the estuary. The changes in biophysical conditions (i.e. supply-side) translated into changes in service demand (i.e. users´ behaviour and perceptions), and the relation between both sides was made explicit for one of the activities building a system dynamics model. Furthermore, the economic valuation revealed that activities cover part of the annual costs needed to preserve the water quality.

Estuaries surrounded by urbanized areas such as Nerbioi estuary, can provide local inhabitants with important benefits that should be carefully considered and protected. Indeed, ecosystem of any type are able to provide benefits, including human-altered ecosystems (Polasky *et al.*, 2015). Furthermore, urban areas such as the villages located along the Nerbioi estuary, depend on nearby sites to cover their high demand for ecosystem services (Palomo *et al.*, 2013). In the current context of global ecosystem services loss (Carpenter *et al.*, 2006; Díaz *et al.*, 2006), restoring ecosystems close to urban areas is vital, as the well-being of an important part of the global population depends on them.

Changes on ecosystem services and human well-being after restoration projects should be incorporated to the monitorization program established to evaluate the project outcomes (Matzek, 2018). However, the incorporation of ecosystem services assessment to the monitoring program of restoration projects faces numerous difficulties due to a lack of funds and expertise. In this thesis, using the case study of the Nerbioi estuary, it has been demonstrated that ecosystem services research has nowadays numerous tools that can be easily adopted by restoration managers in order to track changes on ecosystem services. The results of this thesis are especially valuable for policy-makers, local managers and society at large. First, because it analyses how environmental changes after ecological restoration translated into outputs such as recreational activities. Increase of recreational opportunities can be easily acknowledged by society to restoration projects (Pueyo-Ros *et al.*, 2018), which helps to raise awareness on the important dependency that human well-being has on environment. Second, because in this thesis recreational activities were measured in social and economic terms, providing information on how they are likely to evolve; these measures can be used to inform future decision-making processes. Finally, because ecosystem services assessment in restored areas can help local managers to plan more effectively resource allocation and future restoration efforts (Villamagna *et al.*, 2014b; Jones *et al.*, 2018).

Analysing the changes in recreational services from a triple perspective can give an integrative perspective of restoration and its human benefits. When measuring the success of restoration, changes in ecosystem services should also be considered (De Groot *et al.*, 2013), and those changes should be tracked with information on changes in both the supply and the demand-sides. The consideration of social elements as part of the ecosystem services assessments is vital (Hernández-Morcillo *et al.*, 2013), which has been reinforced in this thesis, as ultimately, the services that an ecosystem delivers are shaped by society (Small *et al.*, 2017). As already mentioned in the Introduction of this thesis, "ecosystem services need human activity to build or maintain human benefits". Results on the important role of the social aspects in ecosystem services go in line with the social-ecological system approach and the idea that complex interactions between natural and non-natural capital are needed for provisioning of ecosystem services.

This thesis focused on recreational services, which is just one type of the **multiple ecosystem services** that the estuary provides, e.g. food provision and water purification. Provisioning services, regulating services and cultural ecosystem services (apart from the analysed recreational services) are present in Nerbioi, but their social and economic importance is unknown. Future studies on ecosystem services in Nerbioi should try to perform a more complete assessment and valuation of the different types of existing services. An extensive ecosystem service assessment would provide the necessary information to analyse trade-offs and synergies between the different services, allowing to better predict the effect of management measures in ecosystem services (Ingraham and Foster, 2008; Villamagna *et al.*, 2014a; Bateman *et al.*, 2016).

A wider assessment of ecosystem services in a restored area could help to assure that none of the services are overlooked. It is important to remember that in restored ecosystems, local inhabitants are known to value mainly the changes in services by changes in recreational opportunities, while the interest of practitioners and managers mainly focuses on other services (Burger, 2003; Junker and Buchecker, 2008; Pueyo-Ros *et al.*, 2018). It is important to **increase social awareness** of the broad number of ecosystem services provided by marine restored ecosystem by driving information campaigns (Pueyo-Ros *et al.*, 2018) and ocean literary.

In ecosystems where many human activities and stakeholders coexist, ecosystem services should be monitored in order to detect changes in human activities (e.g. appearance of new activities, changes in the intensity of them), which could generate new or more intense pressures that could degrade the system and lead to a loss of ecosystem services and human well-being. Monitoring ecosystem services requires the operationalization of the concept (i.e. translate ecosystem services assessment to real world examples) (Jax *et al.*, 2018), a step that has not happened yet. A big challenge on **operationalizing ecosystem services** is the incorporation of non-material and non-use values to ecosystem services assessments (Chan *et al.*, 2012) for avoiding that ecosystem management follows a materialistic and economic approach (Small *et al.*, 2017).

Performing an adequate assessment of ecosystem services implies the analysis of the multiple beneficiaries, the possible conflicts between them for the same resources or space and establishing if any group of beneficiaries could need new management measures (see Introduction - Figure 3 and General Discussion - Figure 6). For example, the demand for one specific activity could affect negatively the supply of other ecosystem services, and conflicts between beneficiaries may arise. Also, value of ecosystem services is dependent of stakeholders (Martino *et al.*, 2019), as some may value higher certain services than others. The analysis of **trade-offs and synergies between ecosystem services** and the conflicts between beneficiaries and stakeholders goes beyond the objective of this thesis but could be an interesting study in the future.

The focus of this thesis was to analyse unidirectionally how changes in biophysical conditions associated to ecological restoration measures might affect the delivery of recreational ecosystem services. If the demand for these activities continues to grow in the future, the pressures in the ecosystem could increase, consequently degrading the ecological conditions and potentially generating a loss of benefits (whether recreational or other types of benefits currently obtained from the estuary)

(Figure 6). The effects that recreational activities generated in the system have not been studied in the thesis but should be considered in future works. Recreational activities are part of the **multiple activities** happening in the estuary. Therefore, they should be integrated in a management plan of Nerbioi (i) as activities that should be preserved for the social and economic benefits they provide, and (ii) as activities that could generate further pressures compromising the ecological integrity of the estuary.

Performing ecosystem services assessment in restored ecosystems helps to advance the understanding of the complex links between ecosystems and human benefits. The ecological restoration measures commonly focus on improving the biophysical conditions; and changes in these conditions are usually monitored as part of the project. If social aspects are incorporated to the monitoring task, advances towards a better comprehension of ecosystem services can be expected, as collecting data on the different elements involved in the ecosystem services provisioning will help to understand how those elements are interlinked and how they react to changes. An integrated ecological and societal perspective is vital for the development of sustainable ecosystem services management (Geijzendorffer *et al.*, 2015).

In the actual context of dramatic degradation rates of ecosystems and global loss of ecosystem services, the findings of the current thesis support the argument towards the vital role that restoration actions play in reversing this global trends (Jones *et al.*, 2018) and the numerous international pledges that have been done to restore damaged ecosystems (e.g. Aichi targets). This thesis proved, using a local case study and following the DAPSI(W)R(M) framework, how investing in restoration ("Response" in the form of "Measures" in the form of passive actions based on the removal of "Pressures") can cause great achievements not only for the ecological integrity of the ecosystem (improvements in "State"), but also in the form of recreational activities that have a social and economic revenue for local inhabitants and visitors (positive impact on "Welfare") (Figure 6).

CONCLUSIONS AND THESIS

Conclusions and thesis

The aim of this thesis was to confirm or refute if changes in the biophysical conditions of a restored estuary can lead to changes in the provisioning of cultural (recreational) ecosystem services. The aim was divided into four objectives that were addressed through the five chapters of the thesis.

From the first objective, *"to evaluate the changes in the natural capital (physical-chemical and biological parameters) recorded in time series that potentially can have an effect in bathing waters and recreational fishing"* (Chapters A and B), the conclusions are:

1. The implementation of the WWTP reduced the microbial concentration in estuarine waters, consequently leading to better conditions of the bathing waters in the three estuarine beaches.
2. The implementation of the WWTP reduced the ammonium concentration and increased the dissolved oxygen in the water, consequently improving fish richness and abundance parameters, and leading to better conditions for recreational fishing.
3. The spatial trend in the recovery of water quality conditions had an influence in the specific biophysical conditions needed for recreation; with recreational fishing conditions being better in the outer than in the inner Nerbioi, and with the more external beaches having better conditions than the innermost beach.

From the second objective, *"to evaluate to which extent the changes in natural capital induced changes in social behaviour and perceptions towards bathing waters´ users and recreational fishers"* (Chapters A and B), the conclusions are:

4. The improvements observed in biophysical conditions have most likely boosted the number of recreationalists in the Nerbioi estuary, as reflected in the increase in recreational fishing licenses and in the importance that beach visitors place to the possibility of practicing aquatic activities when they choose the beach to go.
5. The spatial pattern found in recreationalists´ behaviour suggest that they consider biophysical conditions when deciding where to recreate, as recreational

fishers prefer the outer estuary over the inner estuary and there is a higher percentage of beach visitors practicing aquatic activities in the most external beaches than in the innermost beach.

6. As the condition of key biophysical parameters for fishing improved, recreational fishers have changed their behaviour by progressively entering for recreation to the previously severely polluted inner estuary, following the temporal pattern of restoration.
7. Most recreational users perceive an improvement in water quality, which is positively related with the experience (i.e. number of years recreating in the estuary); and the water improvement is mainly attributed to the implementation of the WWTP.
8. Improvements in environmental conditions do not necessarily translate into positive perceptions (as demonstrated among recreational fishers´ perceptions over fish parameters) or positive behaviour change (as demonstrated for some beach visitors who still do not bathe due to the negative perception on bathing waters conditions).

From the third objective, "*to build a system dynamic model that helps to analyse the provision of the cultural service "recreational fishing" and forecast the effects that different scenarios can cause in the ecosystem services and the recreational activity",* the conclusions are:

9. The analysis of recreational fishing, using a System Dynamics Model (SDM), revealed that after the removal of pressures (untreated wastewater discharges) the estuary is a more resilient system, as reflected in the low affection of short-term acute pressures (future management decisions and unexpected environmental changes) on recreational fishing.
10. The use of SDM tools in ecosystem services assessments allows the consideration of supply and demand-side elements, advancing in the comprehension of the complex relationships between environmental and social drivers in social-ecological systems.
11. SDM can help scientists and managers in planning future management measures, as these models allow to analyse how provisioning of ecosystem

services will change under future management scenarios, being easy to understand and communicate results.

From the fourth objective, *"to perform economic valuations of the two mentioned recreational activities, after the implementation of the restoration measures, using monetary valuation techniques for nonmarket ecosystem services"*, the conclusions are:

12. In Nerbioi, the aggregated use values were estimated in more than 3.5 million € $year^{-1}$ for beach recreation and in 1.12 million € $year^{-1}$ for recreational fishing, amounts that totally cover beach maintenance costs plus an important percentage of the cost needed for maintaining the environmental quality of the estuary.
13. The biophysical conditions and supporting elements conditioned the recreational services demand, as it was reflected in the monetary-value differences of recreational trips between beaches and the differences in the recreational fishing utility values for the different estuarine segments.
14. The analysis of future scenarios revealed that expected socioeconomic changes will not compromise the results of the cost-benefit analysis for beach recreation; while for recreational fishing, the most important changes in economic value will be caused by changes in environmental conditions.

Finally, considering these conclusions, the hypothesis has been confirmed, being the thesis that:

The environmental restoration of estuarine systems contributes to the improvement of their ecological status having positive effects in the provision of ecosystem services and in human well-being, by means of an increase of recreational opportunities. The positive effects of restoration in the provision of ecosystem services have been proved: (i) environmentally, as the overall ecological improvement lead to the amelioration of specific biophysical factors crucial for recreation; (ii) socially, by changes in recreationalists´ behaviour and perceptions over environmental quality improvement; and (ii) economically, since an important percentage of the costs to maintain the water quality is covered by the use-value of recreational activities.

REFERENCES

References

Abdelzaher, A. M., Wright, M. E., Ortega, C., Hasan, A. R., Shibata, T., Solo-Gabriele, H. M., Kish, J., *et al.* 2011. Daily measures of microbes and human health at a non-point source marine beach. Journal of Water and Health, 9: 443.

Abelson, A., Halpern, B. S., Reed, D. C., Orth, R. J., Kendrick, G. A., Beck, M. W., Belmaker, J., *et al.* 2016. Upgrading Marine Ecosystem Restoration Using Ecological–Social Concepts. BioScience: biv171.

Abernethy, K. E., Allison, E. H., Molloy, P. P., and Côté, I. M. 2007. Why do fishers fish where they fish? Using the ideal free distribution to understand the behaviour of artisanal reef fishers. Canadian Journal of Fisheries and Aquatic Sciences, 64: 1595–1604.

Abraham, A., Sommerhalder, K., and Abel, T. 2010. Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. International Journal of Public Health, 55: 59–69.

Adamowicz, W., Louviere, J., and Williams, M. 1994. Combining Revealed and Stated Preference Methods for Valuing Environmental Amenities. Journal of Environmental Economics and Management, 26: 271–292.

Agardy, T., and Alder, J. 2005. Coastal Systems. *In* Ecosystems and human well-being: current state and trends: findings of the condition and trends working group, pp. 513–549. Island Press, Washington, DC.

Ainscough, J., Wilson, M., and Kenter, J. O. 2018. Ecosystem services as a post-normal field of science. Ecosystem Services, 31: 93–101.

Alexandrova, A. 2012. Well-Being as an Object of Science. Philosophy of Science, 79: 678–689.

Alves, B., Ballester, R., Rigall-I-Torrent, R., Ferreira, Ó., and Benavente, J. 2017. How feasible is coastal management? A social benefit analysis of a coastal destination in SW Spain. Tourism Management, 60: 188–200.

Aragonés, L., López, I., Palazón, A., López-Úbeda, R., and García, C. 2016. Evaluation of the quality of coastal bathing waters in Spain through fecal bacteria Escherichia coli and Enterococcus. Science of The Total Environment, 566–567: 288–297.

Ariza, E., Ballester, R., Rigall-I-Torrent, R., Saló, A., Roca, E., Villares, M., Jiménez, J. A., *et al.* 2012. On the relationship between quality, users' perception and economic valuation in NW Mediterranean beaches. Ocean & Coastal Management, 63: 55–66.

Arkema, K. K., Verutes, G. M., Wood, S. A., Clarke-Samuels, C., Rosado, S., Canto, M., Rosenthal, A., *et al.* 2015. Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. Proceedings of the National Academy of Sciences, 112: 7390–7395.

Arlinghaus, R., Mehner, T., and Cowx, I. G. 2002. Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. Fish and Fisheries, 3: 261–316.

Arlinghaus, R., and Mehner, T. 2003. Socio-economic characterisation of specialised common carp (Cyprinus carpio L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. Fisheries Research, 61: 19–33.

Arlinghaus, R., and Mehner, T. 2004. A Management-Orientated Comparative Analysis of Urban and Rural Anglers Living in a Metropolis (Berlin, Germany). Environmental Management, 33: 331–344.
Arlinghaus, R. 2005. A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. Aquatic Resources, Culture and Development, 1: 145–174.
Arlinghaus, R. 2006. On the Apparently Striking Disconnect between Motivation and Satisfaction in Recreational Fishing: The Case of Catch Orientation of German Anglers. North American Journal of Fisheries Management, 26: 592–605.
Arlinghaus, R., Cooke, S., Johnson, B. M., and Anrooy, R. van. 2012. Recreational fisheries. FAO technical guidelines for responsible fisheries. Food and Agriculture Organization of the United Nations, Rome. 176 pp.
Arlinghaus, R., Beardmore, B., Riepe, C., Meyerhoff, J., and Pagel, T. 2014. Species-specific preferences of German recreational anglers for freshwater fishing experiences, with emphasis on the intrinsic utilities of fish stocking and wild fishes: utility of stocking to freshwater anglers. Journal of Fish Biology, 85: 1843–1867.
Arlinghaus, R., Tillner, R., and Bork, M. 2015. Explaining participation rates in recreational fishing across industrialised countries. Fisheries Management and Ecology, 22: 45–55.
Arlinghaus, R., Cooke, S. J., Sutton, S. G., Danylchuk, A. J., Potts, W., Freire, K. de M. F., Alós, J., *et al.* 2016. Recommendations for the future of recreational fisheries to prepare the social-ecological system to cope with change. Fisheries Management and Ecology, 23: 177–186.
Arlinghaus, R., Alós, J., Beardmore, B., Daedlow, K., Dorow, M., Fujitani, M., Hühn, D., *et al.* 2017. Understanding and Managing Freshwater Recreational Fisheries as Complex Adaptive Social-Ecological Systems. Reviews in Fisheries Science & Aquaculture, 25: 1–41.
Aronson, J., Blignaut, J. N., Milton, S. J., Maitre, D. L., Esler, K. J., Limouzin, A., Fontaine, C., *et al.* 2010. Are Socioeconomic Benefits of Restoration Adequately Quantified? A Meta-analysis of Recent Papers (2000-2008) in Restoration Ecology and 12 Other Scientific Journals. Restoration Ecology, 18: 143–154.
Atkins, J. P., Burdon, D., Elliott, M., and Gregory, A. J. 2011. Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin, 62: 215–226.
Australian Government, National Health and Medical Research Council. 2008. Guidelines for managing risks in recreational water. https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh38.pdf (Accessed 31 August 2017).
AZTI. 2011. Perfiles de las aguas de baño de la zona litoral de la CAPV. URA Agencia Vasca del Agua. http://www.uragentzia.euskadi.eus/contenidos/documentacion/azti_ur_diagnostikoa_003/es_def/adjuntos/Perfiles_aguas_2011.pdf (Accessed 2 August 2018).
Badura, T., Bateman, I., Agarwala, M., and Binner, A. 2016. Valuing preferences for ecosystem related goods and services. *In* Routledge handbook of ecosystem

services, pp. 228–242. Ed. by M. Potschin, R. Haines-Young, R. Fish, and R. K. Turner. Routledge, Taylor & Francis Group.

Bald, J., Ibarluzea, J. M., Solaun, O., and Borja, Á. 2004. Microbiological quality. *In* Oceanography and marine environment of the Basque Country, pp. 253–270. Ed. by Á. Borja and M. Collins.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., and Silliman, B. R. 2011. The value of estuarine and coastal ecosystem services. Ecological Monographs, 81: 169–193.

Barbier, E. B., Hacker, S. D., Koch, E. W., Stier, A. C., and Silliman, B. 2012. Estuarine and Coastal Ecosystems and their Services. Chapter 6 in M. van den Belt and R. Costanza (eds.), Volume 12: Ecological Economics of Estuaries and Coasts. Treatise on Estuarine and Coastal Science (Series eds., E. Wolanski, and D. McLusky), Waltham, MA: Academic Press.

Barbier, E. B. 2017. Marine ecosystem services. Current Biology, 27: R507–R510.

Barrella, W., Ramires, M., Rotundo, M. M., Petrere, M., Clauzet, M., and Giordano, F. 2016. Biological and socio-economic aspects of recreational fisheries and their implications for the management of coastal urban areas of south-eastern Brazil. Fisheries Management and Ecology, 23: 303–314.

Barry, L., van Rensburg, T. M., and Hynes, S. 2011. Improving the recreational value of Ireland's coastal resources: A contingent behavioural application. Marine Policy, 35: 764–771.

Barton, K. 2016. MuMIn: Multi-Model Inference. https://CRAN.R-project.org/package=MuMIn.

Basque Government. 2000. Decreto 198/2000 de 3 de octubre, por el que se aprueba el Reglamento de Pesca Marítima Recreativa. 4462.

Bateman, I., Agarwala, M., Binner, A., Coombes, E., Day, B., Ferrini, S., Fezzi, C., *et al.* 2016. Spatially explicit integrated modeling and economic valuation of climate driven land use change and its indirect effects. Journal of Environmental Management, 181: 172–184.

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P., Mumby, P. J., *et al.* 2016. The cost and feasibility of marine coastal restoration. Ecological Applications, 26: 1055–1074.

Beardmore, B., Haider, W., Hunt, L. M., and Arlinghaus, R. 2013. Evaluating the Ability of Specialization Indicators to Explain Fishing Preferences. Leisure Sciences, 35: 273–292.

Belzunce, M. J., Solaun, O., Franco, J., Valencia, V., and Borja, Á. 2001. Accumulation of Organic Matter, Heavy Metals and Organic Compounds in Surface Sediments along the Nervión Estuary (Northern Spain). Marine Pollution Bulletin, 42: 1407–1411.

Belzunce, M. J., Solaun, O., Valencia, V., and Pérez, V. 2004a. Contaminants in estuarine and coastal waters. *In* Oceanography and marine environment of the Basque Country, pp. 233–251. Ed. by Á. Borja and M. Collins.

Belzunce, M. J., Solaun, O., Oreja, J. A. G., Millán, E., and Pérez, V. 2004b. Contaminants in sediments. Elsevier Oceanography Series, 70: 283–315.

Benayas, J. M. R., Newton, A. C., Diaz, A., and Bullock, J. M. 2009. Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis. Science, 325: 1121–1124.

Bergstrom, J. C., Dorfman, J. H., and Loomis, J. B. 2004. Estuary Management and Recreational Fishing Benefits. Coastal Management, 32: 417–432.

Bockstael, N. E., Freeman, A. M., Kopp, R. J., Portney, P. R., and Smith, V. K. 2000. On Measuring Economic Values for Nature. Environmental Science & Technology, 34: 1384–1389.

Boerema, A., and Meire, P. 2017. Management for estuarine ecosystem services: A review. Ecological Engineering, 98: 172–182.

Bonaiuto, M., Breakwell, G. M., and Cano, I. 1996. Identity processes and environmental threat: the effects of nationalism and local identity upon perception of beach pollution. Journal of Community & Applied Social Psychology, 6: 157–175.

Borja, Á., and Collins, M. 2004. Oceanography and marine environment in the Basque Country. Elsevier Oceanography Series. Netherlands. 616 pp.

Borja, Á., Muxika, I., and Franco, J. 2006. Long-term recovery of soft-bottom benthos following urban and industrial sewage treatment in the Nervión estuary (southern Bay of Biscay). Marine Ecology Progress Series, 313: 43–55.

Borja, Á., Dauer, D., Elliott, M., and Simenstad, C. 2010a. Medium- and Long-term Recovery of Estuarine and Coastal Ecosystems: Patterns, Rates and Restoration Effectiveness. Estuaries and Coasts, 33: 1249–1260.

Borja, Á., Elliott, M., Carstensen, J., Heiskanen, A.-S., and van de Bund, W. 2010b. Marine management – Towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin, 60: 2175–2186.

Borja, Á., Murillas-Maza, A., Pascual, M., and Uyarra, M. 2015. Marine and Coastal Ecosystems: Delivery of Goods and Services, Through Sustainable Use and Conservation. *In* Ecosystem Services and River Basin Ecohydrology, pp. 83–105. Ed. by L. Chicharo, F. Müller, and N. Fohrer. Springer Netherlands.

Borja, Á., Elliott, M., Andersen, J. H., Berg, T., Carstensen, J., Halpern, B. S., Heiskanen, A.-S., *et al.* 2016a. Overview of Integrative Assessment of Marine Systems: The Ecosystem Approach in Practice. Frontiers in Marine Science, 3: 10.3389/fmars.2016.00020.

Borja, Á., Chust, G., Rodríguez, J. G., Bald, J., Belzunce-Segarra, M. J., Franco, J., Garmendia, J. M., *et al.* 2016b. 'The past is the future of the present': Learning from long-time series of marine monitoring. Science of The Total Environment, 566–567: 698–711.

Borja, Á., Bald, J., Franco, J., Larreta, J., Menchaca, I., Muxika, I., Revilla, M., *et al.* 2017. Red de seguimiento del estado ecológico de las aguas de transición y costeras de la Comunidad Autónomaa del País Vasco. Informe de resultados 2016. AZTI-Tecnalia. http://www.uragentzia.euskadi.eus/contenidos/documentacion/red_costa_2016/es_red_agua/adjuntos/01_informe_completo_2016_RSEETyC.pdf (Accessed 4 October 2018).

Boyd, J., and Banzhaf, S. 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics, 63: 616–626.

Boyd, J., Ringold, P., Krupnick, A., Johnston, R. J., Weber, M. A., and Hall, K. 2016. Ecosystem Services Indicators: Improving the Linkage between Biophysical and Economic Analyses. International Review of Environmental and Resource Economics, 8: 225–279.

Boyle, K. J. 2003. Introduction to the revealed preference methods. *In* A primer on nonmarket valuation, pp. 259–268. Ed. by P. A. Champ, K. J. Boyle, and T. C. Brown. Springer Netherlands, Dordrecht.

Braat, L. C., Gómez-Baggethun, E., Martín-Lopez, B., Barton, D. N., García-Llorente, M., Kelemen, E., and Saarikoski, H. 2015. Framework for integration of valuation methods to assess ecosystem service policies. Openness project. Deliverable D. 4.2/WP4. http://www.openness-project.eu/sites/default/files/OpenNESS%20D4.2%20Framework_%20Integrated_Valuation_Final_Draft_March_23-2015.pdf (Accessed 2 August 2018).

Bradshaw, A. D. 2002. Introduction and philosophy. *In* Handbook of ecological restoration. Principles of restoration, Cambridge University Press, pp. 3–9. Ed. by M. R. Perrow and A. J. Davy. Cambridge, UK.

Brown, T. C. 2003. Introduction to the stated preference methods. *In* A primer on nonmarket valuation, pp. 99–110. Ed. by P. A. Champ, K. J. Boyle, and T. C. Brown. Springer Netherlands, Dordrecht.

Bullock, C., Joyce, D., and Collier, M. 2018. An exploration of the relationships between cultural ecosystem services, socio-cultural values and well-being. Ecosystem Services, 31: 142–152.

Bullock, J. M., Aronson, J., Newton, A. C., Pywell, R. F., and Rey-Benayas, J. M. 2011. Restoration of ecosystem services and biodiversity: conflicts and opportunities. Trends in Ecology & Evolution, 26: 541–549.

Burger, J. 2003. Assessing perceptions about ecosystem health and restoration options in three east coast estuaries. Environmental Monitoring and Assessment, 83: 145–162.

Burkhard, B., Kroll, F., Nedkov, S., and Müller, F. 2012. Mapping ecosystem service supply, demand and budgets. Ecological Indicators, 21: 17–29.

Cajaraville, M. P., Orive, E., Villate, F., Laza-Martínez, A., Uriarte, I., Garmendia, L., Ortiz-Zarragoitia, M., *et al.* 2016. Health status of the Bilbao estuary: A review of data from a multidisciplinary approach. Estuarine, Coastal and Shelf Science, 179: 124–134.

Cànoves-Valiente, G., Prat-Forga, J., and Blanco-Romero, A. 2016. Tourism in Spain, beyond the sun and the beach. Recent evolution and changes in the destinies of littoral towards a cultural tourism. Boletín de la Asociación de Geógrafos Españoles, 71: 547–551.

Cardona, F., and Morales-Nin, B. 2013. Anglers' perceptions of recreational fisheries and fisheries management in Mallorca. Ocean & Coastal Management, 82: 146–150.

Carpenter, S. R., DeFries, R., Dietz, T., Mooney, H. A., Polasky, S., Reid, W. V., and Scholes, R. J. 2006. Millennium Ecosystem Assessment: research needs. Science, 314: 257–258.

Carpenter, S. R., Mooney, H. A., Agard, J., Capistrano, D., deFriese, R. S., Díaz, S., Dietz, T., *et al.* 2009. Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. PNAS, 106: 1305–1312.

Casado-Arzuaga, I., Madariaga, I., and Onaindia, M. 2013. Perception, demand and user contribution to ecosystem services in the Bilbao Metropolitan Greenbelt. Journal of Environmental Management, 129: 33–43.

Casado-Arzuaga, I., Onaindia, M., Madariaga, I., and Verburg, P. H. 2014. Mapping recreation and aesthetic value of ecosystems in the Bilbao Metropolitan

Greenbelt (northern Spain) to support landscape planning. Landscape Ecology, 29: 1393–1405.
Castillo-Eguskitza, N., Martín-López, B., and Onaindia, M. 2018. A comprehensive assessment of ecosystem services: Integrating supply, demand and interest in the Urdaibai Biosphere Reserve. Ecological Indicators, 93: 1176–1189.
Cearreta, A., and Leorri, E. 2000. La transformación ambiental reciente de la Ría de Bilbao: indicadores micropaleontológicos en el registro sedimentario estuarino. Naturalia Cantabricae, 1: 21–31.
Cearreta, A., Irabien, M. J., Leorri, E., Yusta, I., Croudace, I. W., and Cundy, A. B. 2000. Recent Anthropogenic Impacts on the Bilbao Estuary, Northern Spain: Geochemical and Microfaunal Evidence. Estuarine, Coastal and Shelf Science, 50: 571–592.
Cearreta, A., Irabien, M. J., and Pascual, A. 2004. Human activities along the Basque coast during the last two centuries: geological perspective of recent anthropogenic impact on the coast and its environmental consequences. *In* Oceanography and marine environment in the Basque Country, pp. 27–50. Ed. by Á. Borja and M. Collins. Elsevier.
Champ, P. A., Boyle, K. J., and Brown, T. C. (Eds). 2003. A Primer on Nonmarket Valuation. The Economics of Non-Market Goods and Resources. Springer Netherlands, Dordrecht.
Chan, K. M. A., Satterfield, T., and Goldstein, J. 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics, 74: 8–18.
Chan, K. M. A., Olmsted, P., Bennett, N., Klain, S. C., and Williams, E. A. 2017. Can Ecosystem Services Make Conservation Normal and Commonplace? *In* Conservation for the Anthropocene Ocean, pp. 225–252. Ed. by P. Levin and M. Poe. Elsevier.
Cook, T. C., James, K., and Bearzi, M. 2015. Angler perceptions of California sea lion (Zalophus californianus) depredation and marine policy in Southern California. Marine Policy, 51: 573–583.
Cooper, K., Burdon, D., Atkins, J. P., Weiss, L., Somerfield, P., Elliott, M., Turner, K., *et al.* 2013. Can the benefits of physical seabed restoration justify the costs? An assessment of a disused aggregate extraction site off the Thames Estuary, UK. Marine Pollution Bulletin, 75: 33–45.
Costanza, R., and Daly, H. E. 1992. Natural capital and sustainable development. Conservation Biology, 6: 37–46.
Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., *et al.* 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 253–260.
Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., *et al.* 2014. Changes in the global value of ecosystem services. Global Environmental Change, 26: 152–158.
Costanza, R., de Groot, R., Braat, L., Kubiszewski, I., Fioramonti, L., Sutton, P., Farber, S., *et al.* 2017. Twenty years of ecosystem services: How far have we come and how far do we still need to go? Ecosystem Services, 28: 1–16.
Crawford, I. M. 1997. Marketing research and information systems. Food and Agriculture Organization of the United Nations, Rome.

http://www.fao.org/docrep/w3241e/w3241e00.htm#Contents (Accessed 19 October 2017).

Croissant, Y. 2018. mlogit: Multinomial Logit Models. https://CRAN.R-project.org/package=mlogit.

Cruz Rambaud, S., and Muñoz Torrecillas, M. J. 2006. Social discount rate: a revision. Anales de estudios económicos y empresariales, 16: 75–98.

Cundill, G., Bezerra, J. C., De Vos, A., and Ntingana, N. 2017. Beyond benefit sharing: Place attachment and the importance of access to protected areas for surrounding communities. Ecosystem Services, 28: 140–148.

Danylchuk, A. J., Tiedemann, J., and Cooke, S. J. 2016. Perceptions of recreational fisheries conservation within the fishing industry: Knowledge gaps and learning opportunities identified at east coast trade shows in the United States. Fisheries Research, 186: 681–687.

Davenport, J., and Davenport, J. L. 2006. The impact of tourism and personal leisure transport on coastal environments: A review. Estuarine, Coastal and Shelf Science, 67: 280–292.

De Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., *et al.* 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosystem Services, 1: 50–61.

De Groot, R. S., Wilson, M. A., and Boumans, R. M. J. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, 41: 393–408.

De Groot, R. S., Alkemade, R., Braat, L., Hein, L., and Willemen, L. 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity, 7: 260–272.

De Groot, R. S., Blignaut, J., Van Der Ploeg, S., Aronson, J., Elmqvist, T., and Farley, J. 2013. Benefits of Investing in Ecosystem Restoration. Conservation Biology, 27: 1286–1293.

Defeo, O., McLachlan, A., Schoeman, D. S., Schlacher, T. A., Dugan, J., Jones, A., Lastra, M., *et al.* 2009. Threats to sandy beach ecosystems: A review. Estuarine, Coastal and Shelf Science, 81: 1–12.

Díaz, S., Fargione, J., Chapin, F. S., and Tilman, D. 2006. Biodiversity loss threatens human well-being. PLoS biology, 4: 1300–1305.

Dinno, A. 2017. dunn.test: Dunn's Test of Multiple Comparisons Using Rank Sums. https://CRAN.R-project.org/package=dunn.test.

Duarte, C. M., Conley, D. J., Carstensen, J., and Sánchez-Camacho, M. 2009. Return to Neverland: Shifting Baselines Affect Eutrophication Restoration Targets. Estuaries and Coasts, 32: 29–36.

Duarte, C. M., Borja, Á., Carstensen, J., Elliott, M., Krause-Jensen, D., and Marbà, N. 2015. Paradigms in the Recovery of Estuarine and Coastal Ecosystems. Estuaries and Coasts, 38: 1202–1212.

Earnhart, D. 2001. Combining revealed and stated preference methods to value environmental amenities at residential locations. Land economics, 77: 12–29.

Edwards, P. E. T., Sutton-Grier, A. E., and Coyle, G. E. 2013. Investing in nature: Restoring coastal habitat blue infrastructure and green job creation. Marine Policy, 38: 65–71.

EEA. 2012. Protected areas in Europe - an overview. https://www.eea.europa.eu/publications/protected-areas-in-europe-2012 (Accessed 25 April 2017).

EEA. 2015. State of the environment. Report 2015. European Environmental Agency. https://www.eea.europa.eu/soer (Accessed 13 November 2018).

Elliott, M., Burdon, D., Hemingway, K. L., and Apitz, S. E. 2007. Estuarine, coastal and marine ecosystem restoration: Confusing management and science - A revision of concepts. Estuarine, Coastal and Shelf Science, 74: 349–366.

Elliott, M., and Whitfield, A. K. 2011. Challenging paradigms in estuarine ecology and management. Estuarine, Coastal and Shelf Science, 94: 306–314.

Elliott, M., Burdon, D., Atkins, J. P., Borja, Á., Cormier, R., de Jonge, V. N., and Turner, R. K. 2017. 'And DPSIR begat DAPSI(W)R(M)!' - A unifying framework for marine environmental management. Marine Pollution Bulletin, 118: 27–40.

Elsawah, S., Pierce, S. A., Hamilton, S. H., van Delden, H., Haase, D., Elmahdi, A., and Jakeman, A. J. 2017. An overview of the system dynamics process for integrated modelling of socio-ecological systems: Lessons on good modelling practice from five case studies. Environmental Modelling & Software, 93: 127–145.

European Commission. 1976. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. 76/160/EEC.

European Commission. 2006. Directive 2006/7/EC of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC. 2006/7/EC.

European Commission. 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for the community action in the field of marine environmental policy (Marine Strategy Framework Directive). 2008/56/CE.

European Commission (Ed). 2011. The EU biodiversity strategy to 2020. Publ. Off. of the Europ. Union, Luxembourg. 27 pp.

European Environmental Agency. 2017. European bathing water quality in 2016. EEA Report, 5/2017. European Environmental Agency, Luxembourg. https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2016 (Accessed 6 July 2017).

Eustat. 2014. Proyecciones de poblacion 2026. Análisis de resultados. Euskal Estatistika Erakundea, Eustat. www.eustat.es (Accessed 14 June 2018).

Eustat. 2016. Estadística de Renta Personal y Familiar. Euskal Estatistika Erakundea, Eustat. http://www.eustat.eus/estadisticas/tema_395/opt_0/tipo_1/ti_Renta_personal_y_familiar/temas.html (Accessed 1 October 2019).

Eustat. 2017. Estadística Municipal de Habitantes. Euskal Estatistika Erakundea, Eustat. http://www.eustat.eus/estadisticas/tema_268/opt_1/ti_Estadistica_municipal_de_habitantes/temas.html (Accessed 10 April 2018).

Everard, M. 2012. Why does 'good ecological status' matter? Water and Environment Journal, 26: 165–174.

Ezebilo, E. E. 2016. Economic value of a non-market ecosystem service: an application of the travel cost method to nature recreation in Sweden. International Journal of Biodiversity Science, Ecosystem Services & Management, 12: 314–327.

Farber, S. C., Costanza, R., and Wilson, M. A. 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics, 41: 375–392.

Fedler, A. J., and Ditton, R. B. 1986. A framework for understanding the consumptive orientation of recreational fishermen. Environmental Management, 10: 221–227.

Fedler, A. J., and Ditton, R. B. 1994. Understanding angler motivations in fisheries management. Fisheries, 19: 6–13.

Fedler, A. J., and Ditton, R. B. 2000. Developing a National Outreach Strategy for Recreational Fishing and Boating. Fisheries, 25: 22–28.

Fenichel, E. P., Abbott, J. K., and Huang, B. 2013. Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature: Modelling angler behaviour. Fish and Fisheries, 14: 137–157.

Ferrini, S., Schaafsma, M., and Bateman, I. 2014. Revealed and stated preference valuation and transfer: A within-sample comparison of water quality improvement values. Water Resources Research, 50: 4746–4759.

Festinger, L. 1957. A theory of cognitive dissonance. Stanford University Press, Stanford, California.

Fezzi, C., Bateman, I. J., and Ferrini, S. 2014. Using revealed preferences to estimate the Value of Travel Time to recreation sites. Journal of Environmental Economics and Management, 67: 58–70.

Fife, D. 2017. fifer: A Biostatisticians Toolbox for Various Activities, Including Plotting, Data Cleanup, and Data Analysis. https://CRAN.R-project.org/package=fifer.

Fulford, R., Yoskowitz, D., Russell, M., Dantin, D., and Rogers, J. 2016. Habitat and recreational fishing opportunity in Tampa Bay: Linking ecological and ecosystem services to human beneficiaries. Ecosystem Services, 17: 64–74.

Garcia Rodrigues, J., Conides, A., Rivero Rodriguez, S., Raicevich, S., Pita, P., Kleisner, K., Pita, C., *et al.* 2017. Marine and Coastal Cultural Ecosystem Services: knowledge gaps and research priorities. One Ecosystem, 2: e12290.

García-Barcina, J. M., Oteiza, M., and de la Sota, A. 2002. Modelling the faecal coliform concentrations in the Bilbao estuary. *In* Nutrients and Eutrophication in Estuaries and Coastal Waters, pp. 213–219. Ed. by E. Orive, M. Elliott, and V. N. de Jonge.

García-Barcina, J. M., González-Oreja, J. A., and De la Sota, A. 2006. Assessing the improvement of the Bilbao estuary water quality in response to pollution abatement measures. Water Research, 40: 951–960.

Garrod, G., and Willis, K. G. 1999. Economic Valuation of the Environment. Books. Edward Elgar Publishing.

Geijzendorffer, I. R., Martín-López, B., and Roche, P. K. 2015. Improving the identification of mismatches in ecosystem services assessments. Ecological Indicators, 52: 320–331.

Ghaffarzadegan, N., Lyneis, J., and Richardson, G. P. 2010. How small system dynamics models can help the public policy process. System Dynamics Review, 27: 22–44.

Ghermandi, A., Nunes, P. A. L. D., Portela, R., Rao, N., and Teelucksingh, S. S. 2012. Recreational, cultural and aesthetic services from estuarine and coastal ecosystems. Chapter 11 in M. van den Belt and R. Costanza (eds.), Volume 12: Ecological Economics of Estuaries and Coasts. Treatise on Estuarine and Coastal Science (Series eds., E. Wolanski, and D. McLusky), Waltham, MA: Academic Press: 217–237.

Giardina, A., Larson, S. F., Wisner, B., Wheeler, J., and Chao, M. 2009. Long-term and acute effects of zinc contamination of a stream on fish mortality and physiology. Environmental toxicology and chemistry, 28: 287–295.

Given, S., Pendleton, L. H., and Boehm, A. B. 2006. Regional Public Health Cost Estimates of Contaminated Coastal Waters:? A Case Study of Gastroenteritis at Southern California Beaches. Environmental Science & Technology, 40: 4851–4858.

Gómez-Baggethun, E., and Ruiz-Pérez, M. 2011. Economic valuation and the commodification of ecosystem services. Progress in Physical Geography, 35: 613–628.

Gómez-Baggethun, E., Martín-López, B., Barton, D., Braat, L., Saarikoski, H., Kelemen, E., García-Llorente, M., *et al.* 2014. State-of-the-art report on integrated valuation of ecosystem services. EU FP7 OpenNESS Project Deliverable 4.1. http://www.openness-project.eu/sites/default/files/Deliverable%204%201_Integrated-Valuation-Of-Ecosystem-Services.pdf (Accessed 10 May 2018).

González, S. A., and Holtmann-Ahumada, G. 2017. Quality of tourist beaches of northern Chile: A first approach for ecosystem-based management. Ocean & Coastal Management, 137: 154–164.

Google Maps. 2018. Google Maps. https://www.google.es/maps.

Gormsen, E. 1997. The impact of tourism on coastal areas. GeoJournal, 42: 39–54.

Gorostiaga, J. M., Borja, Á., Díez, I., Francés, G., Pagola-Carte, S., and Sáiz-Salinas, J. I. 2004. Recovery of benthic communities in polluted systems. Elsevier Oceanography Series, 70: 549–578.

Granek, E. F., Madin, E. M., Brown, M. A., Figueira, W., Cameron, D. S., Hogan, Z., Kristianson, G., *et al.* 2008. Engaging recreational fishers in management and conservation: global case studies. Conservation Biology, 22: 1125–1134.

Griffiths, S. P., Bryant, J., Raymond, H. F., and Newcombe, P. A. 2017. Quantifying subjective human dimensions of recreational fishing: does good health come to those who bait? Fish and Fisheries, 18: 171–184.

Grifoll, M., Del Campo, A., Espino, M., Mader, J., González, M., and Borja, Á. 2013. Water renewal and risk assessment of water pollution in semi-enclosed domains: Application to Bilbao Harbour (Bay of Biscay). Journal of Marine Systems, 109–110: S241–S251.

Haab, T. C., and McConnell, K. E. 2002. Valuing Environmental and Natural Resources: The Econometrics of Non-market Valuation. New Horizons in Environmental Economics Series. Edward Elgar Publishing, Cheltenham, UK. 352 pp.

Haines-Young, R., and Potschin, M. 2013. Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. Report to the European Environment Agency, EEA Framework Contract No: EEA/IEA/09/003. https://www.nottingham.ac.uk/cem/pdf/CICES%20V43_Revised%20Final_Report_29012013.pdf (Accessed 23 March 2017).

Haines-Young, R., and Potschin, M. 2018. Common International Classification of Ecosystem Services (CICES) V5.1 and guidance on the application of the revised structure. Fabis consulting. https://cices.eu/content/uploads/sites/8/2018/01/Guidance-V51-01012018.pdf (Accessed 21 September 2018).

Haines-Young, R. H., and Potschin, M. P. 2010. The links between biodiversity, ecosystem services and human well-being. *In* Ecosystem Ecology: A New Synthesis., Raffaelli, D., Frid, C., pp. 110–139. CUP, Cambridge.

Hall, C. M. 2001. Trends in ocean and coastal tourism: the end of the last frontier? Ocean & coastal management, 44: 601–618.

Hampton, E. L., and Lackey, R. T. 1976. Analysis of angler preferences and fisheries management objectives with implications for management. Proceedings of the Southeastern Association Game and Fish Commissioners, 29: 310–316.

Hattam, C., Atkins, J. P., Beaumont, N., Börger, T., Böhnke-Henrichs, A., Burdon, D., Groot, R. de, *et al.* 2015. Marine ecosystem services: Linking indicators to their classification. Ecological Indicators, 49: 61–75.

Health Canada. 2012. Guidelines for Canadian recreational water quality. Ottawa, Ontario. 155 pp. http://epe.lac-bac.gc.ca/100/201/301/weekly_checklist/2012/internet/w12-44-U-E.html/collections/collection_2012/sc-hc/H129-15-2012-eng.pdf (Accessed 6 July 2017).

Heiberger, R. M. 2017. HH: Statistical Analysis and Data Display: Heiberger and Holland. https://CRAN.R-project.org/package=HH.

Hernández-Morcillo, M., Plieninger, T., and Bieling, C. 2013. An empirical review of cultural ecosystem service indicators. Ecological Indicators, 29: 434–444.

Hinkel, J., Bots, P. W. G., and Schlüter, M. 2014. Enhancing the Ostrom social-ecological system framework through formalization. Ecology and Society, 19: 51.

Hinkel, J., Cox, M. E., Schlüter, M., Binder, C. R., and Falk, T. 2015. A diagnostic procedure for applying the social-ecological systems framework in diverse cases. Ecology and Society, 20: 32.

Hollander, M., Wolfe, D. A., and Chicken, E. 2014. Nonparametric statistical methods. Wiley, New Jersey.

Hoyos, D., Mariel, P., and Fernández-Macho, J. 2009. The influence of cultural identity on the WTP to protect natural resources: Some empirical evidence. Ecological Economics, 68: 2372–2381.

Hunt, L. M. 2005. Recreational Fishing Site Choice Models: Insights and Future Opportunities. Human Dimensions of Wildlife, 10: 153–172.

Hutniczak, B., and Münch, A. 2018. Fishermen's location choice under spatio-temporal update of expectations. Journal of Choice Modelling, 28: 124–136.

Ibarluzea, J. M., Gardeazabal, M. J., Santa Marina, L., and Irigoien, I. 2000. Calidad del agua de baño de las playas del País Vasco. 1985-1998: análisis temporales. Eusko Jaurlaritzaren Argitalpen Zerbitzu Nagusia, Vitoria-Gasteiz. 175 pp.

Ingraham, M. W., and Foster, S. G. 2008. The value of ecosystem services provided by the U.S. National Wildlife Refuge System in the contiguous U.S. Ecological Economics, 67: 608–618.

Irabien, M. J., Cearreta, A., Serrano, H., and Villasante-Marcos, V. 2018. Environmental regeneration processes in the Anthropocene: The Bilbao estuary case (northern Spain). Marine Pollution Bulletin, 135: 977–987.

Jackson, J. B. C. 2001. Historical Overfishing and the Recent Collapse of Coastal Ecosystems. Science, 293: 629–637.

Jacobs, S., Dendoncker, N., Martín-López, B., Barton, D. N., Gomez-Baggethun, E., Boeraeve, F., McGrath, F. L., *et al.* 2016. A new valuation school: Integrating

diverse values of nature in resource and land use decisions. Ecosystem Services, 22: 213–220.
Jax, K. 2005. Function and 'functioning' in ecology: what does it mean? Oikos, 111: 641–648.
Jax, K., and Heink, U. 2016. Human Well-being. *In* OpenNESS Ecosystem Services Reference Book, EC FP7 Grant Agreement no. 308428. Ed. by M. Potschin and K. Jax. http://www.openness-project.eu/library/reference-book/sp-human-well-being (Accessed 11 August 2018).
Jax, K., Furman, E., Saarikoski, H., Barton, D. N., Delbaere, B., Dick, J., Duke, G., *et al.* 2018. Handling a messy world: Lessons learned when trying to make the ecosystem services concept operational. Ecosystem Services, 29: 415–427.
Jenkins, J., and Pigram, J. 2006. Outdoor recreation management. Routledge, Oxford, UK. 444 pp.
Jin, G., Englande, A. J., Bradford, H., and Jeng, H.-W. 2004. Comparison of E. coli, Enterococci, and Fecal Coliform as indicators for brackish water quality assessment. Water Environment Research, 76: 245–255.
Jones, H. P., Jones, P. C., Barbier, E. B., Blackburn, R. C., Rey Benayas, J. M., Holl, K. D., McCrackin, M., *et al.* 2018. Restoration and repair of Earth's damaged ecosystems. Proceedings of the Royal Society B: Biological Sciences, 285: 20172577.
Junker, B., and Buchecker, M. 2008. Aesthetic preferences versus ecological objectives in river restorations. Landscape and Urban Planning, 85: 141–154.
Kahle, D., and Wickham, H. 2013. ggmap: Spatial Visualization with ggplot2. The R Journal, 5: 144–161.
Kinzelman, J., Ng, C., Jackson, E., Gradus, S., and Bagley, R. 2003. Enterococci as Indicators of Lake Michigan Recreational Water Quality: Comparison of Two Methodologies and Their Impacts on Public Health Regulatory Events. Applied and Environmental Microbiology, 69: 92–96.
Kreitler, J., Papenfus, M., Byrd, K., and Labiosa, W. 2013. Interacting Coastal Based Ecosystem Services: Recreation and Water Quality in Puget Sound, WA. PLoS ONE, 8: e56670.
Kulczyk, S., Woźniak, E., and Derek, M. 2018. Landscape, facilities and visitors: An integrated model of recreational ecosystem services. Ecosystem Services, 31: 491–501.
Kumar, M., and Kumar, P. 2008. Valuation of the ecosystem services: A psycho-cultural perspective. Ecological Economics, 64: 808–819.
Laniak, G. F., Olchin, G., Goodall, J., Voinov, A., Hill, M., Glynn, P., Whelan, G., *et al.* 2013. Integrated environmental modeling: A vision and roadmap for the future. Environmental Modelling & Software, 39: 3–23.
Lau, J. D., Hicks, C. C., Gurney, G. G., and Cinner, J. E. 2018. Disaggregating ecosystem service values and priorities by wealth, age, and education. Ecosystem Services, 29: 91–98.
Leorri, E., Cearreta, A., Irabien, M. J., and Yusta, I. 2008. Geochemical and microfaunal proxies to assess environmental quality conditions during the recovery process of a heavily polluted estuary: The Bilbao estuary case (N. Spain). Science of The Total Environment, 396: 12–27.

Liquete, C., Piroddi, C., Drakou, E. G., Gurney, L., Katsanevakis, S., Charef, A., and Egoh, B. 2013. Current Status and Future Prospects for the Assessment of Marine and Coastal Ecosystem Services: A Systematic Review. PLoS ONE, 8: e67737.

Liu, S., Costanza, R., Farber, S., and Troy, A. 2010. Valuing ecosystem services. Annals of the New York Academy of Sciences, 1185: 54–78.

Loomis, D. K., and Paterson, S. K. 2014. Human dimensions indicators of coastal ecosystem services: A hierarchical perspective. Ecological Indicators, 44: 63–68.

Lotze, H. K., Lenihan, H. S., Bourque, B. J., Bradbury, R. H., Cooke, R. G., Kay, M. C., Kidwell, S. M., *et al.* 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science, 312: 1806–1809.

Lotze, H. K. 2010. Historical reconstruction of human-induced changes in U.S. estuaries. Oceanography and Marine Biology: an Annual Review, 48: 267–338.

Lynam, C. P., Cusack, C., and Stokes, D. 2010. A methodology for community-level hypothesis testing applied to detect trends in phytoplankton and fish communities in Irish waters. Estuarine, Coastal and Shelf Science, 87: 451–462.

Mace, G. M., Norris, K., and Fitter, A. H. 2012. Biodiversity and ecosystem services: a multilayered relationship. Trends in Ecology & Evolution, 27: 19–26.

Mace, G. M. 2014. Whose conservation? Science, 345: 1558–1560.

Martin, C. L., Momtaz, S., Jordan, A., and Moltschaniwskyj, N. A. 2016. Exploring recreational fishers' perceptions, attitudes, and support towards a multiple-use marine protected area six years after implementation. Marine Policy, 73: 138–145.

Martín-López, B., Montes, C., and Benayas, J. 2007. Influence of user characteristics on valuation of ecosystem services in Doñana Natural Protected Area (south-west Spain). Environmental Conservation, 34: 215–224.

Martín-López, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I., Amo, D. G. D., Gómez-Baggethun, E., *et al.* 2012. Uncovering Ecosystem Service Bundles through Social Preferences. PLoS ONE, 7: e38970.

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., and Montes, C. 2014. Trade-offs across value-domains in ecosystem services assessment. Ecological Indicators, 37: 220–228.

Martino, S., Tett, P., and Kenter, J. 2019. The interplay between economics, legislative power and social influence examined through a social-ecological framework for marine ecosystems services. Science of The Total Environment, 651: 1388–1404.

Matzek, V. 2018. Turning delivery of ecosystem services into a deliverable of ecosystem restoration: Measuring restoration's contribution to society. Restoration Ecology, 26: 1013–1016.

Matzek, V., Wilson, K. A., and Kragt, M. 2019. Mainstreaming of ecosystem services as a rationale for ecological restoration in Australia. Ecosystem Services, 35: 79–86.

Mavrommati, G., Bithas, K., and Panayiotidis, P. 2013. Operationalizing sustainability in urban coastal systems: A system dynamics analysis. Water Research, 47: 7235–7250.

Mayer, M., and Woltering, M. 2018. Assessing and valuing the recreational ecosystem services of Germany's national parks using travel cost models. Ecosystem Services, 31: 371–386.

McFadden, D. 1973. Conditional logit analysis of qualitative choice behavior. *In* Frontiers in econometrics, pp. 105–142. Ed. by P. Zarembka. Elsevier Academic Press, New York.
Metcalfe, P. J., Baker, W., Andrews, K., Atkinson, G., Bateman, I. J., Butler, S., Carson, R. T., *et al.* 2012. An assessment of the nonmarket benefits of the Water Framework Directive for households in England and Wales. Water Resources Research, 48: W03526.
Metro Bilbao. 2018. Metro Bilbao: map and frequencies. https://www.metrobilbao.eus/utilizando-el-metro/mapa-y-frecuencias (Accessed 14 June 2018).
Milcu, A. I., Hanspach, J., Abson, D., and Fischer, J. 2013. Cultural Ecosystem Services: A Literature Review and Prospects for Future Research. Ecology and Society, 18: 44.
Millennium Ecosystem Assessment. 2003. Ecosystems and human well-being: a framework for assessment. Island Press, Washington, DC. 245 pp.
Millennium Ecosystem Assessment (Ed). 2005a. Ecosystems and human well-being: synthesis. Island Press, Washington, DC. 137 pp.
Millennium Ecosystem Assessment. 2005b. Ecosystems and human well-being: wetlands and water. Synthesis. Washington, DC. 80 pp.
Monjo, R., Chust, G., and Caselles, V. 2014. Probabilistic correction of RCM precipitation in the Basque Country (Northern Spain). Theoretical and Applied Climatology, 117: 317–329.
Murray, J. 2013. Likert data: what to use, parametric or non-parametric? International Journal of Business and Social Science, 4: 258–264.
Nutsford, D., Pearson, A. L., Kingham, S., and Reitsma, F. 2016. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. Health & Place, 39: 70–78.
Ofiara, D. D., and Seneca, J. J. 2006. Biological effects and subsequent economic effects and losses from marine pollution and degradations in marine environments: Implications from the literature. Marine Pollution Bulletin, 52: 844–864.
O'Higgins, T. G., Ferraro, S. P., Dantin, D. D., Jordan, S. J., and Chintala, M. M. 2010. Habitat scale mapping of fisheries ecosystem service values in estuaries. Ecology and Society, 15: art7.
Ohimain, E. I., Jonathan, G., and Abah, S. O. 2008. Variations in heavy metal concentrations following the dredging of an oil well access canal in the Niger Delta. Advances in Biological Research, 2: 97–103.
Olander, L. P., Johnston, R. J., Tallis, H., Kagan, J., Maguire, L. A., Polasky, S., Urban, D., *et al.* 2018. Benefit relevant indicators: Ecosystem services measures that link ecological and social outcomes. Ecological Indicators, 85: 1262–1272.
Osbaldiston, R., and Schott, J. P. 2012. Environmental Sustainability and Behavioral Science: Meta-Analysis of Proenvironmental Behavior Experiments. Environment and Behavior, 44: 257–299.
Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. Proceedings of the national Academy of sciences, 104: 15181–15187.
Ostrom, E. 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science, 325: 419–422.

Outeiro, L., Ojea, E., Garcia Rodrigues, J., Himes-Cornell, A., Belgrano, A., Liu, Y., Cabecinha, E., *et al.* 2017. The role of non-natural capital in the co-production of marine ecosystem services. International Journal of Biodiversity Science, Ecosystem Services & Management, 13: 35–50.

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R., and Montes, C. 2013. National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows. Ecosystem Services, 4: 104–116.

Paltriguera, L., Ferrini, S., Luisetti, T., and Turner, R. K. 2018. An analysis and valuation of post-designation management aimed at maximising recreational benefits in coastal Marine Protected Areas. Ecological Economics, 148: 121–130.

Parsons, G. R. 2003. The Travel Cost Model. *In* A Primer on Nonmarket Valuation, pp. 269–329. Ed. by P. A. Champ, K. J. Boyle, and T. C. Brown. Springer Netherlands, Dordrecht.

Parsons, G. R., and Massey, D. M. 2003. A Random Utility Model of Beach Recreation. *In* The New Economics of Outdoor Recreation, pp. 241–267. Edward Elgar Publishing.

Pascual, M., Borja, Á., Franco, J., Burdon, D., Atkins, J. P., and Elliott, M. 2012. What are the costs and benefits of biodiversity recovery in a highly polluted estuary? Water Research, 46: 205–217.

Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., and Verma, M. 2010. The economics of valuing ecosystem services and biodiversity. *In* The economics of ecosystems and biodiversity: the ecological and economic foundations, pp. 183–256. Ed. by P. Kumar. Earthscan, London and Washington.

Pasquaud, S., Vasconcelos, R. P., França, S., Henriques, S., Costa, M. J., and Cabral, H. 2015. Worldwide patterns of fish biodiversity in estuaries: Effect of global vs. local factors. Estuarine, Coastal and Shelf Science, 154: 122–128.

Patterson, T., Gulden, T., Cousins, K., and Kraev, E. 2004. Integrating environmental, social and economic systems: a dynamic model of tourism in Dominica. Ecological Modelling, 175: 121–136.

Pawson, M. G., Glenn, H., and Padda, G. 2008. The definition of marine recreational fishing in Europe. Marine Policy, 32: 339–350.

Pearce, D. W., and Turner, R. K. 1990. Economics of natural resources and the environment. 378 pp.

Pendleton, L., and Mendelsohn, R. 2000. Estimating recreation preferences using hedonic travel cost and random utility models. Environmental and Resource Economics, 17: 89–108.

Pendleton, L., Martin, N., and Webster, D. G. 2001. Public perceptions of environmental quality: a survey study of beach use and perceptions in Los Angeles County. Marine Pollution Bulletin, 42: 1155–1160.

Pendleton, L. 2010. The economic and market value of coasts and estuaries: What’s at stake? Restore America’s Estuaries, USA. https://www.estuaries.org/images/stories/docs/policy-legislation/final-econ-with-cover-5-20-2008.pdf (Accessed 20 June 2018).

Peng, M., and Oleson, K. L. L. 2017. Beach Recreationalists’ Willingness to Pay and Economic Implications of Coastal Water Quality Problems in Hawaii. Ecological Economics, 136: 41–52.

Pereira, D. G., Afonso, A., and Medeiros, F. M. 2015. Overview of Friedman’s Test and Post-hoc Analysis. Communications in Statistics - Simulation and Computation, 44: 2636–2653.

Pita, P., Artetxe, I., Diogo, H., Gomes, P., Gordoa, A., Hyder, K., Pereira, J., *et al.* 2017. Research and management priorities for Atlantic marine recreational fisheries in Southern Europe. Marine Policy, 86: 1–8.

Pohlert, T. 2014. The Pairwise Multiple Comparison of Mean Ranks Package (PMCMR). https://CRAN.R-project.org/package=PMCMR.

Pokki, H., Artell, J., Mikkola, J., Orell, P., and Ovaskainen, V. 2018. Valuing recreational salmon fishing at a remote site in Finland: A travel cost analysis. Fisheries Research, 208: 145–156.

Polasky, S., Tallis, H., and Reyers, B. 2015. Setting the bar: Standards for ecosystem services. Proceedings of the National Academy of Sciences, 112: 7356–7361.

Prayaga, P. 2017. Estimating the value of beach recreation for locals in the Great Barrier Reef Marine Park, Australia. Economic Analysis and Policy, 53: 9–18.

Prüss, A. 1998. Review of epidemiological studies on health effects from exposure to recreational water. International journal of epidemiology, 27: 1–9.

Pueyo-Ros, J., Ribas, A., and Fraguell, R. M. 2018. A cultural approach to wetlands restoration to assess its public acceptance: Public acceptance of wetlands restoration. Restoration Ecology, Advance online publication: doi:10.1111/rec.12896.

Quilliam, R. S., Kinzelman, J., Brunner, J., and Oliver, D. M. 2015. Resolving conflicts in public health protection and ecosystem service provision at designated bathing waters. Journal of Environmental Management, 161: 237–242.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Regional Government of Bizkaia. 2018. Listado de playas de Bizkaia. http://www.bizkaia.eus/Ingurugiroa_Lurraldea/Hondartzak/listadoplayas.asp?Tem_Codigo=350&idioma=CA&dpto_biz=2&codpath_biz=2|350 (Accessed 1 August 2018).

Ressurreição, A., Simas, A., Santos, R. S., and Porteiro, F. 2012. Resident and expert opinions on marine related issues: Implications for the ecosystem approach. Ocean & Coastal Management, 69: 243–254.

Reyers, B., Biggs, R., Cumming, G. S., Elmqvist, T., Hejnowicz, A. P., and Polasky, S. 2013. Getting the measure of ecosystem services: a social–ecological approach. Frontiers in Ecology and the Environment, 11: 268–273.

Ribaudo, M. O., and Piper, S. L. 1991. Estimating changes in recreational fishing participation from national water quality policies. Water Resources Research, 27: 1757–1763.

Rivas, V. 1991. Evolución reciente y estado actual del litoral cantábrico oriental. Universidad de Murcia. 537 pp.

Robertson, R. A., and Caporossi, G. 2003. New England recreational fisher´s attitudes toward marine protected areas: a preliminary investigation. *In* Proceedings of the 2003 Northeastern Recreation Research Symposium, pp. 121–127. Citeseer.

Roca, E., and Villares, M. 2008. Public perceptions for evaluating beach quality in urban and semi-natural environments. Ocean & Coastal Management, 51: 314–329.

Roca, E., Riera, C., Villares, M., Fragell, R., and Junyent, R. 2008. A combined assessment of beach occupancy and public perceptions of beach quality: A case study in the Costa Brava, Spain. Ocean & Coastal Management, 51: 839–846.

Rouillard, J., Lago, M., Abhold, K., Röschel, L., Kafyeke, T., Mattheiß, V., and Klimmek, H. 2018. Protecting aquatic biodiversity in Europe: How much do EU environmental policies support ecosystem-based management? Ambio, 47: 15–24.

Rubens, L., Gosling, P., Bonaiuto, M., Brisbois, X., and Moch, A. 2015. Being a hypocrite or committed while I am shopping? A comparison of the impact of two interventions on environmentally friendly behavior. Environment and Behavior, 47: 3–16.

Ruiz, J., Zarauz, L., Urtizberea, A., Andonegi, E., Mugerza, E., and Artetxe, I. 2014. Establecimiento de un sistema de recogida sistemática de datos sobre pesca recreativa. Eusko Jaurlaritza - Gobierno Vasco. http://www.euskadi.eus/contenidos/informacion/proyectos_fep/es_def/adjuntos/Recrea%202012.pdf (Accessed 2 August 2019).

Sanchez-Lorenzo, A., Brunetti, M., Calbó, J., and Martin-Vide, J. 2007. Recent spatial and temporal variability and trends of sunshine duration over the Iberian Peninsula from a homogenized data set. Journal of Geophysical Research, 112: D20115.

Sartori, D., and European Commission (Eds). 2015. Guide to cost-benefit analysis of investment projects: economic appraisal tool for cohesion policy 2014 - 2020. Publ. Office of the Europ. Union, Luxembourg. 358 pp.

Saveriades, A. 2000. Establishing the social tourism carrying capacity for the tourist resorts of the east coast of the Republic of Cyprus. Tourism management, 21: 147–156.

Schlacher, T. A., Schoeman, D. S., Jones, A. R., Dugan, J. E., Hubbard, D. M., Defeo, O., Peterson, C. H., *et al.* 2014. Metrics to assess ecological condition, change, and impacts in sandy beach ecosystems. Journal of Environmental Management, 144: 322–335.

Schmitt Olabisi, L. K., Kapuscinski, A. R., Johnson, K. A., Reich, P. B., Stenquist, B., and Draeger, K. J. 2010. Using Scenario Visioning and Participatory System Dynamics Modeling to Investigate the Future: Lessons from Minnesota 2050. Sustainability, 2: 2686–2706.

Sheaves, M., Johnston, R., and Connolly, R. M. 2012. Fish assemblages as indicators of estuary ecosystem health. Wetlands Ecology and Management, 20: 477–490.

Small, N., Munday, M., and Durance, I. 2017. The challenge of valuing ecosystem services that have no material benefits. Global Environmental Change, 44: 57–67.

Souto Nieves, G. 2001. Tasas de descuento para la evaluación de inversiones públicas: estimaciones para España. 8/03. Instituto de Estudios Fiscales, Madrid.

Spangenberg, J. H., and Settele, J. 2010. Precisely incorrect? Monetising the value of ecosystem services. Ecological Complexity, 7: 327–337.

Spanish Government. 1988. Real Decreto 734/1988, de 1 de julio, por el que se establecen normas de calidad de las aguas de baño. 734/1988.

Spanish Government. 2007. Real Decreto 1341/2007, de 11 de octubre, sobre la gestión de la calidad de las aguas de baño. 1341/2007.

Spanish Government. 2014. Real Decreto 876/2014, de 10 de octubre, por el que se aprueba el reglamento general de costas. 876/2014.

Spooren, P., Mortelmans, D., and Denekens, J. 2007. Student evaluation of teaching quality in higher education: development of an instrument based on 10 Likert-scales. Assessment & Evaluation in Higher Education, 32: 667–679.
Spurgeon, J. 1998. The socio-economic costs and benefits of coastal habitat rehabilitation and creation. Marine Pollution Bulletin, 37: 373–382.
Summers, J. K., Smith, L. M., Case, J. L., and Linthurst, R. A. 2012. A Review of the Elements of Human Well-Being with an Emphasis on the Contribution of Ecosystem Services. Ambio, 41: 327–340.
Sutton, S. G. 2007. Constraints on recreational fishing participation in Queensland, Australia. Fisheries, 32: 73–83.
Sutton, S. G., and Tobin, R. C. 2009. Recreational fishers' attitudes towards the 2004 rezoning of the Great Barrier Reef Marine Park. Environmental Conservation, 36: 245–252.
Syrbe, R.-U., and Walz, U. 2012. Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. Ecological Indicators, 21: 80–88.
Szostek, C. L., Murray, L. G., Bell, E., and Kaiser, M. J. 2017. Filling the gap: Using fishers' knowledge to map the extent and intensity of fishing activity. Marine Environmental Research, 129: 329–346.
Teixeira, H., Lillebø, A., Culhane, F., Robinson, L., Trauner, D., Borgwardt, F., Kummerlen, M., *et al.* 2019. Linking biodiversity to ecosystem services supply: Patterns across aquatic ecosystems. Science of The Total Environment, 657: 517–534.
Thøgersen, J. 2004. A cognitive dissonance interpretation of consistencies and inconsistencies in environmentally responsible behavior. Journal of Environmental Psychology, 24: 93–103.
Thomas, A. S., Milfont, T. L., and Gavin, M. C. 2015. What determines fishers' knowledge of and attitudes towards regulations? A case study from the Marlborough Sounds, New Zealand. Marine Policy, 51: 547–554.
Tudor, D. T., and Williams, A. T. 2003. Public perception and opinion of visible beach aesthetic pollution: the utilisation of photography. Journal of Coastal Research, 19: 1104–1115.
Turner, K. G., Anderson, S., Gonzales-Chang, M., Costanza, R., Courville, S., Dalgaard, T., Dominati, E., *et al.* 2016. A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. Ecological Modelling, 319: 190–207.
Turner, R. K., and Daily, G. C. 2008. The Ecosystem Services Framework and Natural Capital Conservation. Environmental and Resource Economics, 39: 25–35.
Turner, R. K., Morse-Jones, S., and Fisher, B. 2010. Ecosystem valuation. A sequential decision support system and quality assessment issues. Annals of the New York Academy of Sciences, 1185: 79–101.
Turner, R. K., and Schaafsma, M. (Eds). 2015. Coastal Zones Ecosystem Services. Studies in Ecological Economics. Springer International Publishing, Switzerland. 240 pp.
Turner, R. K. 2016. The 'Balance Sheet' approach within adaptive management for ecosystem services. *In* Routledge handbook of ecosystem services, pp. 289–303. Ed. by M. Potschin, R. Haines-Young, R. Fish, and R. K. Turner. Routledge, Taylor & Francis Group.

United Nations. 1992. Convention on biological diversity. https://www.cbd.int/doc/legal/cbd-en.pdf (Accessed 19 November 2018).

United Nations. 2016. Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. E/CN.3/2016/2/Rev.1. United Nations Economic and Social Council, New York.

Uriarte, A., and Borja, Á. 2009. Assessing fish quality status in transitional waters, within the European Water Framework Directive: Setting boundary classes and responding to anthropogenic pressures. Estuarine, Coastal and Shelf Science, 82: 214–224.

Uriarte, I., Villate, F., Iriarte, A., Duque, J., and Ameztoy, I. 2014. Seasonal and axial variations of net water circulation and turnover in the estuary of Bilbao. Estuarine, Coastal and Shelf Science, 150: 312–324.

US Government. 2000. Beaches environmental assessment and coastal health act of 2000. 33 U.S.C. 1251.

Uyarra, M. C., Gill, J. A., and Côté, I. M. 2010. Charging for Nature: Marine Park Fees and Management from a User Perspective. Ambio, 39: 515–523.

Verdonschot, P. F. M., Spears, B. M., Feld, C. K., Brucet, S., Keizer-Vlek, H., Borja, A., Elliott, M., *et al.* 2013. A comparative review of recovery processes in rivers, lakes, estuarine and coastal waters. Hydrobiologia, 704: 453–474.

Vesterinen, J., Pouta, E., Huhtala, A., and Neuvonen, M. 2010. Impacts of changes in water quality on recreation behavior and benefits in Finland. Journal of Environmental Management, 91: 984–994.

Viana, D., Gornik, K., Lin, C.-C., McDonald, G., Ng, N. S. R., Quigley, C., and Potoski, M. 2017. Recreational boaters value biodiversity: The case of the California Channel Islands National Marine Sanctuary. Marine Policy, 81: 91–97.

Villamagna, A. M., Angermeier, P. L., and Bennett, E. M. 2013. Capacity, pressure, demand, and flow: A conceptual framework for analyzing ecosystem service provision and delivery. Ecological Complexity, 15: 114–121.

Villamagna, A. M., Angermeier, P. L., and Niazi, N. 2014a. Evaluating opportunities to enhance ecosystem services in public use areas. Ecosystem Services, 7: 167–176.

Villamagna, A. M., Mogollón, B., and Angermeier, P. L. 2014b. A multi-indicator framework for mapping cultural ecosystem services: The case of freshwater recreational fishing. Ecological Indicators, 45: 255–265.

Voke, M., Fairley, I., Willis, M., and Masters, I. 2013. Economic evaluation of the recreational value of the coastal environment in a marine renewables deployment area. Ocean & Coastal Management, 78: 77–87.

Ward, H. G. M., Allen, M. S., Camp, E. V., Cole, N., Hunt, L. M., Matthias, B., Post, J. R., *et al.* 2016. Understanding and Managing Social–Ecological Feedbacks in Spatially Structured Recreational Fisheries: The Overlooked Behavioral Dimension. Fisheries, 41: 524–535.

Williams, G. D., and Zedler, J. B. 1999. Fish assemblage composition in constructed and natural tidal marshes of San Diego Bay: relative influence of channel morphology and restoration history. Estuaries, 22: 702–716.

Wilson, M., Costanza, R., Boumans, R., and Liu, S. 2005. Integrated assessment and valuation of ecosystem goods and services provided by coastal systems. The Intertidal Ecosystem: The Value of Ireland's Shores. Dublin: Royal Irish Academy: 1–24.

Wolff, S., Schulp, C. J. E., and Verburg, P. H. 2015. Mapping ecosystem services demand: A review of current research and future perspectives. Ecological Indicators, 55: 159–171.

World Forum on Natural Capital. 2018. What is natural capital? https://naturalcapitalforum.com/about/ (Accessed 11 August 2018).

Wright, D. A., and Welbourn, P. M. 1994. Cadmium in the aquatic environment: a review of ecological, physiological, and toxicological effects on biota. Environmental Reviews, 2: 187–214.

Young, M. A. L., Foale, S., and Bellwood, D. R. 2016. Why do fishers fish? A cross-cultural examination of the motivations for fishing. Marine Policy, 66: 114–123.

Zarauz, L., Ruiz, J., Urtizberea, A., Andonegi, E., Mugerza, E., and Artetxe, I. 2015. Comparing different survey methods to estimate European sea bass recreational catches in the Basque Country. ICES Journal of Marine Science, 72: 1181–1191.

Ziv, G., Mullin, K., Boeuf, B., Fincham, W., Taylor, N., Villalobos-Jiménez, G., von Vittorelli, L., *et al.* 2016. Water Quality Is a Poor Predictor of Recreational Hotspots in England. PLOS ONE, 11: e0166950.

Zuur, A. F., Ieno, E. N., and Smith, G. M. 2007. Analysing ecological data. Statistics for biology and health. Springer, New York ; London. 672 pp.

Zuur, A. F., Ieno, E. N., and Elphick, C. S. 2010. A protocol for data exploration to avoid common statistical problems: Data exploration. Methods in Ecology and Evolution, 1: 3–14.

APPENDICES

__Appendix A1__ – Survey on beaches at Nerbioi estuary

SECTION 1. GENERAL CHARACTERIZATION OF THE BEACH USER

1. **Gender,**
   - ☐ Woman ☐ Man
2. **Age**…………………years old.
3. **Post code of the village where you live nowadays** ....
4. **Since when do you live in that village?** ....
5. **Which is your current employment status?**
   - ☐ Employee *Profession* ……………………………………………………………………………
   - ☐ Self-employed *Profession* ……………………………………………………………………………
   - ☐ Unemployed *Profession* ……………………………………………………………………………
   - ☐ Retired *Last profession*...
   - ☐ Student
   - ☐ Homemaker
   - ☐ Other
6. **Completed education up-to-date:**
   - ☐ None
   - ☐ Primary studies
   - ☐ Secondary studies
   - ☐ University or higher

SECTION 2. GENERAL INTEREST ON BEACHES

7. **Choose your MAIN MOTIVES for going to the beach. Choose a MAXIMUM OF THREE.**
   - ☐ To walk along the shore
   - ☐ To sunbathe
   - ☐ To play aquatic sports (surf, snorkel…)
   - ☐ To swim / to cool down in the sea
   - ☐ To play sports on the sand (volleyball, beach paddle…)
   - ☐ To rest / Relax
   - ☐ To work
   - ☐ Other reasons. Which?...........
8. **When you CHOOSE TO VISIT A BEACH, how important is that there is the possibility to practice aquatic activities (e.g. surfing, swimming)? Choose the correct answer:**

   Essential   Important   Of little importance   Not important   No answer

9. **Please state the effect (positive or negative) that the following WATER CHARACTERISTICS have on your enjoyment of AQUATIC ACTIVITIES in beaches. For each characteristic, mark with an X the corresponding box.**

	EFFECT					
	Highly positive + +	**Positive** +	**No effect** =	**Negative** -	**Highly negative** - -	**No answer**
Murky water (lack of transparency)						
Water odour						
Cold water						
Presence of rocks in the water						
Strong waves						
Strong currents						

	EFFECT					
	Highly positive	**Positive**	**No effect**	**Negative**	**Highly negative**	**No answer**
Absence of fish						
Presence of jellyfish						
Presence of seaweeds, branches and plant debris						
Presence of marine debris						
Presence of foams on the water						
Oils on the water						
Presence of wastewater spills nearby						
Presence of boats (sailboats, yatchs…)						
Presence of people practicing aquatic sports (e.g. surf, bodyboard)						
Presence of numerous bathers						
No delimitation between bathing area and aquatic sports						
Other characteristic. Which?						

SECTION 3: CHARACTERIZATION OF TODAY´S VISIT

10. From where did you come today to the beach?

- ☐ From home (habitual residence)
- ☐ From work. *Which town?* ………………………………………………………………………………
- ☐ From the place where I am hosted →

  Provide type of accommodation (second home, hotel…)………………………

  Provide town/city……………………………………………………………………………

- ☐ From another place. *Which town / city?* …………………………………………………………

11. Which TRANSPORT did you use to arrive to the beach?

- ☐ Car
- ☐ Organized trip
- ☐ Foot
- ☐ Bike
- ☐ Public transport. *Which?*.......................................
- ☐ Other. *Which?*.................................

12. How long did it take you to arrive to the beach? ………………… minutes

13. For how long are you planning to stay in the beach?…………………… hours

14. Did you come with somebody to the beach?

- ☐ No, I came alone
- ☐ Yes, I came with →

14a. Who? Mark all the responses that apply:

- ☐ Couple
- ☐ Pet
- ☐ Others. *Who?*....................
- ☐ Friends
- ☐ Relatives

14b. How many of them are less than 14 years old? ………..

15. Today, how much do you expect to expend on your visit to the beach? Please, if any of the options does not apply, write NA.

- Accommodation .... €/day per person
- Transport to the beach (petrol, bus ticket, car park...) ....€/day per person
- Food and beverage ....€/day per person
- Rental of sport equipment, loungers… ....€/ day per person
- Others. *Which?* ....€/ day per person

16. Why did you choose TO COME TO THIS BEACH TODAY (Mark a MAXIMUM OF THREE):

- ☐ Close to home / close to accommodation
- ☐ Close to work
- ☐ Family-related reasons
- ☐ Recommendation
- ☐ Accessibility (good connections, public transport, car parks…)
- ☐ Beach facilities and services (showers, toilets, lifeguards…)
- ☐ Tranquillity / Relax
- ☐ General cleanliness of the beach
- ☐ Bathing water quality
- ☐ It is a safe beach for bathing (sea currents, waves…)
- ☐ Others. *Which?*...

17. Have you practiced TODAY or do you USUALLY practice any aquatic activity in THIS BEACH? (e.g. bathing or swimming, snorkel, surfing, windsurfing...)

☐ No. *Why?*...

☐ Yes →

17a. Which activity? Mark all the responses that apply:

- ☐ Bathing / Refreshing in the sea
- ☐ Windsurfing
- ☐ Swimming
- ☐ Paddle surfing
- ☐ Surfing
- ☐ Snorkel
- ☐ Bodyboard
- ☐ Spearfishing
- ☐ Other. *Which?*................................

17b. How satisfied are you with the practice of those activities in this beach?

Completely satisfied	Satisfied	Little satisfied	Unsatisfied	No answer

18. Assess your general satisfaction with your visit to beach today.

Completely satisfied	Satisfied	Little satisfied	Unsatisfied	No answer

18b. Why are you little or not satisfied?

....

19. Will you come back to this beach?

Sure	Probably	Rarely probable	Not probable	No answer

SECTION 4. QUALITY OF THE BEACH AND ITS BATHING WATER

20. Do you believe that bathing IN THIS BEACH has any health effect?

- ☐ Yes, a positive effect. *In which sense?*...
- ☐ Yes, a negative effect. *In which sense?*..
- ☐ I believe it has no health effect
- ☐ NA

21. How do you perceive the condition of the following characteristics in this beach? For each characteristic, mark with an X the corresponding box.

	Excellent	Good	Average	Bad	No answer
Accessibility to the beach (public transport, car parks…)					
Restaurants, beach bars… nearby					
Safety (lifeguards, beach watchmen….)					
General services (toilets, showers...)					
General cleanness (sand, waste collection…)					
Recreational activity opportunities (surfing courses, kayaking…)					
Sport facilities (e.g. volleyball nets)					
Scenery					
Tranquillity					
Sand type (thickness, colour…)					
Shade availability					
Bathing water quality					
Water transparency					
Water odour					
Water temperature					
Rocks in water					
Waves					
Sea currents					
Fish					
Jellyfish					
Seaweeds, branches and plant debris in water					
Marine debris					
Foams on the water					
Oils on the water					
Proximity to wastewater spills					
Number of motorboats nearby (sailboats, boats...)					
Number of people practicing aquatic sports (surfing, bodyboarding…)					
Number of swimmers					
Delimitation between bathing area and aquatic sports					

22. Which decisions do you think that will be more effective in this beach for the improvement of the bathing water quality? Mark a maximum of three options.

- ☐ Closure of the industries located nearby
- ☐ Improve the controls of industrial spills
- ☐ Higher control of domestic spills
- ☐ Higher control of water runoff after storms
- ☐ Restrict the access of motorboats
- ☐ Increase cleaning actions on bathing waters
- ☐ Higher environmental awareness of beach users
- ☐ Restrict the number of bathers
- ☐ Others. *Which?* …………………………
- ☐ NA

SECTION 4: EXPERIENCED VISITORS´ PERCEPTIONS ON BEACH CHANGES

23. Is today your first visit to this beach?

- ☐ No
- ☐ Yes → *You have finished answering the questionnaire! Thanks for your collaboration. If you wish to leave any comment, please go to page 12.*

24. How often do you come to this beach? (Select one option from each column)

IN SUMMER:	REST OF THE YEAR:
☐ Every day or almost everyday	☐ Every day or almost everyday
☐ More than once a week or every weekend	☐ More than once a week or every weekend
☐ Once a week	☐ Once a week
☐ Once a fortnight	☐ Once a fortnight
☐ Once a month	☐ Once a month
☐ Less than once a month	☐ Less than once a month
	☐ Never (I only come during summer)

25. From the first time you came this beach, the frequency of your visits has changed??

- ☐ No, I come with the same frequency
- ☐ Yes, the frequency has changed ↓

25a. How frequently did you come to this beach when you started to visit it?

IN SUMMER	REST OF THE YEAR
☐ Every day or almost everyday	☐ Every day or almost everyday
☐ More than once a week or every weekend	☐ More than once a week or every weekend
☐ Once a week	☐ Once a week
☐ Once a fortnight	☐ Once a fortnight
☐ Once a month	☐ Once a month
☐ Less than once a month	☐ Less than once a month
	☐ Never (I only came during summer)

26. For how many bathing seasons have you been coming to this beach? *(Bathing season is the period between June and September).*

- ☐ This is the first season (2016)
- ☐ For 1-6 seasons (2015 - 2010)
- ☐ For 7-15 seasons (2009 - 2001)
- ☐ For 16-20 seasons (2000-1996)
- ☐ For more than 20 seasons (1995 or before)

27. From the first time you visited THIS BEACH until today, you believe that the quality of the bathing water has…

Improved   Got worse   Not changed   NA

27a. Which motives have influenced more in the IMPROVEMENT OF THE BATHING WATER IN THIS BEACH? Mark a maximum of three options.

- ☐ Toughening of the legislation on bathing waters, wastewater spills…
- ☐ Closure of polluting industries located nearby
- ☐ Sanitation of the wastewaters spilled to Nerbioi estuary
- ☐ Higher public investment in beach cleanness
- ☐ Higher social awareness on environmental issues
- ☐ Better maritime facilities (ports)
- ☐ Decrease in the number of bathers
- ☐ Others. *Which?*……………………………………………….
- ☐ NA

27b. How important is the improvement of the bathing water quality in your decision to visit this beach?

- ☐ Essential
- ☐ Important
- ☐ Little importance
- ☐ Not important
- ☐ NA

27c. Which motives have influenced more in the WORSENING OF THE BATHING WATER IN THIS BEACH? Mark a maximum of three options.

- ☐ Proximity to domestic spills
- ☐ Proximity to WWTP spills
- ☐ Proximity to polluting industries
- ☐ Increase of debris from storm runoff
- ☐ Decrease of public investment in beach cleanness
- ☐ Lower social awareness on environmental issues
- ☐ Construction of shore promenades, jetties, ports…
- ☐ Proximity to marinas and fishing ports
- ☐ Higher number of bathers
- ☐ Others. *Which?*…………………………………….
- ☐ NA

28. From the first time you visited this beach, you believe that the number of visitors has…

Highly increased	Increased	Not changed	Decreased	Highly decreased	No answer

29. How probable is that you will not come back if any of the following situations occur in this beach? Mark the corresponding box for each of the hypothetical situations:

I will not come back to this beach if…	**Sure**	**Probably**	**Rarely probable**	**Not probable**	**No answer**
… facilities get worse (showers, toilets…).					
… safety services get worse (lifeguards, beach watchmen…).					
… influx of visitors increase.					
… debris on sand increase.					
… people practicing aquatic sports (e.g. surfing, bodyboarding) increased					
… maritime traffic increase (big and small boats).					
…. number of harmful species increase (e.g. jellyfish).					
… water odour get worse.					
… marine debris in water increase.					
… foams on water surface increase.					
… oil spills in the water surface increase.					
… bathing is forbidden due to the deficient water quality.					
… (other motives). *Which ones?* ………………………………………………………………..					

SECTION 5. ECOSYSTEM SERVICES

Nature provides benefits that increase human well-being in a direct (e.g. food provision) and indirect (e.g. recreation and enjoyment of outdoor activities). These benefits are known as ecosystem services.

30. Before reading the definition above, did you know what ecosystem services were?

☐ Yes ☐ No ☐ NA

31. Do you think that this beach provides any of those services?

☐ Yes ☐ No ☐ NA

32. If a non-governmental organization (NGO) decided to create a FUND to improve the ecosystem services in this beach (improvement of recreational activities, of the visit experience, of the wellness that produces…) will you collaborate with them?

☐ No. *Why?*..

☐ Yes. *How much?*....................................€/year

33. If you could choose how to collaborate, in which way would you prefer to do it?

☐ Voluntary donation to an environmental organization

☐ Paying extra taxes

☐ Donating 0.7% of the annual tax return

☐ Voluntary work in this beach, by monthly spending time on conservation or nature restoration activities.

How much time would you spend?...hours/year

☐ I would not collaborate in any of these ways.

Why? ……………..

How will you colaborate? ……………...

34. Monthly household income (sum of all salaries at home after income-tax and social security contributions):

a. Less than 650 €/month
b. 650-1.300 €/month
c. 1.301-1.850 €/month
d. 1.851-2.400 €/month
e. 2.401-2.950 €/month
f. 2.951-3.500 €/month
g. 3.501-4.050 €/month
h. More than 4.051 €/month
i. No answer (NA)

35. How many people depend on that income?

………..adults and ……….. < 18 years old

THANKS FOR YOUR COLABORATION!

If you wish to receive the result of this study, please write bellow your email or your postal address and we will send you a brief report.

………

Do you want to make any suggestion or give us feedback? Please write bellow:

………
………
………

***Appendix A Table 1 -** Socioeconomic aspects of Nerbioi beaches´ visitors. Significant differences after the corresponding statistical test are indicated as *p<0.05; **p<0.01; ***p<0.001; not significant as ns. Different lettering (a,b,c) indicates if significant differences exist between beaches (for the corresponding Post Hoc Test p<0.05).*

	Areeta	Ereaga	Arrigunaga	Total	
	n (%)	n (%)	n (%)	n (%)	Statistical test
Gender	*a*	*b*	*ab*		
Women	83 (83.0)	158 (69.6)	76 (76.8)	317 (74.4)	Chi squared X^2: 6.920*
Men	17 (17.0)	69 (30.4)	23 (23.2)	109 (25.6)	
Age	*a*	*a*	*a*		
Mean ± SD	43.8 ± 16.2	41 ± 16.1	42.3 ± 15.8	42 ± 16.1	Kruskal Wallis H: 2.109 (ns)
Employment	*a*	*b*	*b*		
Employee	38 (38.0)	118 (52.0)	55 (55.6)	211 (49.5)	Chi squared X^2: 23.29*
Self-employed	8 (8.0)	10 (4.4)	6 (6.1)	24 (5.6)	
Unemployed	10 (10.0)	15 (6.6)	7 (7.1)	32 (7.5)	
Retired	16 (16.0)	23 (10.1)	12 (12.1)	51 (12.0)	
Student	10 (10.0)	39 (17.2)	11 (11.1)	60 (14.1)	
Homemaker	13 (13.0)	9 (4.0)	3 (3.0)	25 (5.9)	
Other	5 (5.0)	13 (5.7)	5 (5.1)	23 (5.4)	
Education	*a*	*b*	*a*		
None or primary	20 (20.0)	44 (19.4)	13 (13.1)	77 (18.1)	Chi squared X^2: 14.47**
Secondary	25 (25.0)	91 (40.1)	27 (27.3)	143 (33.6)	
Higher education	54 (54.0)	91 (40.1)	59 (59.6)	204 (47.9)	
NA	*1 (1.0)*	*1 (0.4)*	*0 (0.0)*	*2 (0.5)*	
Residence	*a*	*b*	*c*		
Getxo	42 (42)	44 (19.7)	71 (71.7)	157 (36.9)	Chi squared X^2: 85.14***
Others.Nerbioi	48 (48)	132 (59.2)	21 (21.2)	201 (47.2)	
Others.Bizkaia	4 (4)	33 (14.8)	5 (5.1)	42 (9.9)	
Others	6 (6)	14 (6.3)	2 (2.0)	22 (5.2)	
NA	*0*	*4 (1.8)*	*0*	*4 (0.9)*	

***Appendix A Table 2 -** Main motivations to go to the beach. Each respondent could mark a maximum of three motivations. NR: no response.*

	Areeta		Ereaga		Arrigunaga		Total	
	n	%	n	%	n	%	n	%
Sunbathe	85	85.0	199	87.7	83	83.8	367	86.2
Relaxing and resting	70	70.0	165	72.7	75	75.8	310	72.8
Bathing, cool down	58	58.0	134	59.0	80	80.8	272	63.8
Walk along the shore	21	21.0	84	37.0	26	26.3	131	30.8
Aquatic sports	6	6.0	6	2.6	6	6.1	18	4.2
Sand sports	2	2.0	7	3.1	4	4.0	13	3.1
Other	4	4.0	6	2.6	0	0.0	10	2.3
NR	*1*	*1.0*	*2*	*0.9*	*0*	*0.0*	3	0.7

Appendix A Table 3 - *Effect of water characteristics in the enjoyment of water activities. n: number of respondents; they could mark if the characteristic had any effect or not (no effect (NE) columns); mean: calculated from the total number of user´s who answered that the characteristic had an effect (from 1 very negative to 1 very positive). Level of significance after Kruskal-Wallis test is indicated as *p<0.05; **p<0.01; ***p<0.001. Different lettering (A,B) indicate significant differences between beaches (Dunn´s Test with Bonferroni corrections).*

	Areeta				**Ereaga**				**Arrigunaga**				**All**		**Kruskal-Wallis**
	n	**NE**	**Mean**	**SD**	**n**	**NE**	**Mean**	**SD**	**n**	**NE**	**Mean**	**SD**	**Mean**	**SD**	**H**
Murky water	99	4	1.54	0.58	220	11	1.56	0.59	98	9	1.48	0.52	1.53	0.58	0.616
Water odour	99	0	1.20	0.47	220	1	1.13	0.35	98	0	1.09	0.29	1.14	0.37	3.764
Cold water	96	63	2.09	0.46	215	138	2.04	0.64	97	66	2.06	0.57	2.06	0.58	0.422
Rocks in water	97	39	1.91^{A}	0.28	217	70	1.77^{B}	0.48	99	33	1.70^{B}	0.50	1.78	0.46	**8.398***
Strong waves	98	37	2.05	0.72	221	92	1.98	0.66	99	45	1.98	0.69	2.00	0.68	0.360
Strong currents	99	14	1.65	0.50	220	36	1.69	0.46	97	12	1.64	0.48	1.67	0.48	1.027
Absence of fish	96	62	1.97	0.97	218	134	2.17	0.79	97	53	2.18	0.84	2.13	0.84	2.656
Presence of jellyfish	97	2	1.31	0.58	218	7	1.29	0.57	99	3	1.24	0.50	1.28	0.55	0.611
Presence of seaweeds, and branches and plant debris	97	20	1.70	0.56	219	43	1.69	0.51	99	30	1.80	0.53	1.71	0.53	2.093
Marine debris	99	0	1.16	0.45	220	1	1.10	0.30	99	0	1.08	0.27	1.11	0.33	2.296
Foams on the water	97	11	1.47	0.59	220	27	1.40	0.49	99	9	1.53	0.50	1.45	0.52	4.421
Oils on the water	99	2	1.16	0.45	218	1	1.13	0.34	99	0	1.17	0.38	1.15	0.38	0.788
Wastewater spills nearby	97	0	1.21	0.41	221	1	1.15	0.35	99	1	1.13	0.34	1.16	0.36	2.432
Presence of motorboats	98	50	1.88	0.49	218	102	1.87	0.58	97	47	1.84	0.37	1.86	0.52	0.095
People practicing aquatic sports	98	73	2.72	0.68	220	155	2.58	0.75	99	78	2.52	0.68	2.60	0.72	1.603
Numerous swimmers	98	67	2.48	0.68	218	140	2.54	0.72	98	58	2.25	0.59	2.45	0.68	4.380
No delimitation between bathing area and aquatic sports	99	32	1.96	0.51	220	55	1.88	0.54	98	31	1.78	0.49	1.87	0.52	3.598

Appendix A Table 4 - *Why did you choose this beach today? A maximum of three options could be selected.*

	Areeta		**Ereaga**		**Arrigunaga**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Proximity to accommodation	92	92.0	180	79.3	77	77.8	349	81.9
Accesibility	24	24.0	87	38.3	35	35.4	146	34.3
Tranquility	37	37.0	61	26.9	34	34.3	132	31.0
Services	10	10.0	35	15.4	19	19.2	64	15.0
Safe beach for bathing	14	14.0	41	18.1	9	9.1	64	15.0
Cleanness	8	8.0	37	16.3	16	16.2	61	14.3
Water quality	0	0.0	26	11.5	1	1.0	27	6.3
Near work	4	4.0	17	7.5	2	2.0	23	5.4
Family	3	3.0	3	1.3	8	8.1	14	3.3
Recomendation	0	0.0	6	2.6	0	0.0	6	1.4
Others	7	7.0	23	10.1	7	7.1	37	8.7

Appendix A Table 5 - *Transport used to arrive to the beach. NR: No response.*

	Areeta		**Ereaga**		**Arrigunaga**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Car	11	11.0	133	58.6	31	31.3	175	41.1
Walking	59	59.0	38	16.7	52	52.5	149	35.0
Public transport	29	29.0	48	21.1	13	13.1	90	21.1
Bike	0	0.0	3	1.3	1	1.0	4	0.9
Organized trip	0	0.0	0	0.0	1	1.0	1	0.2
Other	1	1.0	3	1.3	1	1.0	5	1.2
NR	*0*	*0.0*	*2*	*0.9*	*0*	*0.0*	*2*	*0.5*

Appendix A Table 6 - *Level of visitor´s satisfaction with the visit to the beach. NR: No response.*

	Areeta		**Ereaga**		**Arrigunaga**		**Total**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Completely satisfied	19	19.0	46	20.3	19	19.2	84	19.7
Satisfied	71	71.0	170	74.9	68	68.7	309	72.5
Slightly satisfied	8	8.0	6	2.6	10	10.1	24	5.6
Not at all satisfied	2	2.0	1	0.4	2	2.0	5	1.2
NR	0	0.0	4	1.8	0	0.0	4	0.9

Appendix A Table 7 - *When did visitors start to visit the beach? Results are split by beach and indicated as total number (n) and percentage (%). NR: No response.*

	Areeta		Ereaga		Arrigunaga		Total	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Today first day	10	10	13	5.7	6	6.1	29	6.8
2016 first year	7	7.0	5	2.2	2	2.0	14	3.3
2010-2015	24	24.0	55	24.2	16	16.2	95	22.3
2001-2009	16	16.0	43	18.9	16	16.2	75	17.6
1996-2000	8	8.0	24	10.6	15	15.2	47	11.0
=<1995	35	35.0	83	36.6	44	44.4	162	38.0
NR	0	0.0	4	1.8	0	0.0	4	0.9

Appendix A Table 8 - *General and individual beach valuation for 29 characteristics. Values are in a scale from 1=bad to 4=excellent. Significant differences after Kruskal-Wallis test are indicated as *p<0.05; **p<0.01; ***p<0.001. Different lettering (A,B,C) at the "Mean" columns indicate if significant differences exist between beaches (Dunn´s Test with Bonferroni correction p-value<0.05).*

	Areeta			**Ereaga**			**Arrigunaga**			**Total**			**Kruskal Wallis (*H*)**
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	
Accessibility to the beach	97	3.21 A	0.74	223	2.94 B	0.76	99	3.14 A	0.67	419	3.1	0.74	**10.25****
Restaurants, beach bars nearby	90	2.30 A	0.91	215	2.95 B	0.76	97	2.94 B	0.64	402	2.8	0.81	**38.23*****
Safety	96	3.25	0.58	220	3.15	0.59	98	3.23	0.55	414	3.2	0.58	2.52
General services	97	3.13 A	0.59	223	2.68 B	0.87	98	2.89 AB	0.74	418	2.8	0.80	**20.27*****
General cleanness	97	2.79	0.72	220	2.70	0.81	99	2.74	0.76	416	2.7	0.78	1.22
Recreational activity opportunities	58	1.31 A	0.60	113	1.70 B	0.75	65	1.42 A	0.61	236	1.5	0.70	**15.16*****
Sport facilities	62	1.18 A	0.46	127	1.73 B	0.77	73	1.30 A	0.59	262	1.5	0.70	**36.52*****
Scenery	99	2.83 A	0.76	225	2.79 A	0.84	98	3.17 B	0.73	422	2.9	0.81	**15.82*****
Tranquillity	99	3.00	0.69	222	3.01	0.61	99	3.10	0.66	420	3.0	0.64	1.66
Sand type	98	2.57	0.70	223	2.52	0.82	98	2.31	0.89	419	2.5	0.81	5.33
Shade availability	92	1.48	0.70	206	1.52	0.68	89	1.37	0.61	387	1.5	0.67	3.42
Bathing water quality	91	2.00 A	0.82	219	2.47 B	0.81	98	2.34 B	0.92	408	2.3	0.86	**18.96*****
Water transparency	95	1.92	0.75	217	2.04	0.81	96	2.01	0.76	408	2.0	0.78	1.438
Water odour	84	2.31 A	0.73	208	2.54 B	0.66	93	2.57 B	0.61	385	2.5	0.67	**7.63***
Water temperature	90	2.60 A	0.68	217	2.73 AB	0.67	97	2.88 B	0.62	404	2.7	0.67	**8.44***
Rocks in water	85	2.49 A	0.73	213	2.36 A	0.74	98	1.69 B	0.71	396	2.2	0.79	**58.55*****
Waves	86	3.03 A	0.73	220	2.82 B	0.64	98	2.62 C	0.60	404	2.8	0.66	**20.35*****
Sea currents	76	3.08 A	0.65	186	2.75 AB	0.67	85	2.62 B	0.60	347	2.8	0.67	**8.44***
Fish	70	2.43	0.79	159	2.42	0.79	71	2.21	0.75	300	2.4	0.78	3.88
Jellyfish	67	3.12 A	0.93	163	2.94 AB	0.87	76	2.76 B	0.99	306	2.9	0.92	**6.11***
Seaweeds, branches and plant debris	76	2.37 A	0.85	205	2.32 A	0.88	96	2.02 B	0.82	377	2.3	0.86	**9.43****

	Areeta			Ereaga			Arrigunaga			Total			Kruskal Wallis (*H*)
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	
Marine debris	87	2.07	0.89	207	2.30	0.86	91	2.14	0.94	385	2.2	0.89	5.78
Foams on the water	87	2.21	0.90	204	2.36	0.86	91	2.27	0.88	382	2.3	0.87	2.04
Oils on the water	78	2.14 [A]	0.91	195	2.51 [B]	0.90	89	2.34 [AB]	0.90	362	2.4	0.91	**9.83****
Proximity to wastewater spills	70	2.14	1.01	165	2.27	0.92	77	2.38	1.00	312	2.3	0.96	2.32
Motorboats nearby	77	2.47 [A]	0.90	199	2.74 [B]	0.73	90	2.84 [B]	0.90	366	2.7	0.82	**10.15****
People practicing aquatic sports	73	2.52	0.96	195	2.73	0.86	84	2.70	0.85	352	2.7	0.88	2.78
Swimmers	92	2.79	0.67	213	2.95	0.56	99	2.87	0.55	404	2.9	0.59	4.1
Delimitation between bathing area and aquatic sports	63	2.27	1.05	156	2.29	0.90	74	2.15	0.99	293	2.2	0.96	1.06

Appendix A Table 9 - *Perception of changes in water quality from the respondents who began to visit the beach before 2010 (n=284). Responses are split by the visited beach. NR: no response.*

	Better		**Worse**		**Equal**		**NR**		**TOTAL**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Areeta	49	83.1	1	1.7	6	10.2	3	5.1	59	100.0
Ereaga	126	84.0	9	6.0	11	7.3	4	2.7	150	100.0
Arrigunaga	60	80.0	7	9.3	7	9.3	1	1.3	75	100.0
TOTAL	**235**	**82.7**	**17**	**6.0**	**24**	**8.5**	**8**	**2.8**	**284**	**100.0**

Appendix A Table 10 - *Perception of changes in the number of visitors from the respondents who began to visit the beach before 2010 (n=284). Responses are split by (a) Beach and (b) year when they began visiting Nerbioi beaches. NR: no response.*

	High increase		**Slight increase**		**No change**		**Slight decrease**		**High decrease**		***NR***		***TOTAL***	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
(a) Beach														
Areeta	31	52.5	14	23.7	13	22.0	0	0.0	0	0.0	1	1.7	59	100
Ereaga	58	38.7	44	29.3	29	19.3	13	8.7	1	0.7	5	3.3	150	100
Arrigunaga	51	68.0	14	18.7	5	6.7	0	0.0	0	0.0	5	6.7	75	100
(b) Experience														
2001-2009	27	36.0	21	28.0	21	28.0	1	1.3	0	0.0	5	6.7	75	100
1996-2000	23	48.9	11	23.4	7	14.9	3	6.4	0	0.0	3	6.4	47	100
=< 1995	90	55.6	40	24.7	19	11.7	9	5.6	1	0.6	3	1.9	162	100
TOTAL	**140**	**49.3**	**72**	**25.4**	**47**	**16.5**	**13**	**4.6**	**1**	**0.4**	**12**	**4.2**	**284**	**100**

Appendix A Table 11 - *Perceptions of experienced visitors (n=284) on ecosystem services. Level of significance after Chi-square test is indicated as *p<0.05; **p<0.01; ***p<0.001; ns: p>0.05. Different lettering (A,B) indicates if significant differences exist between beaches (for Chi Squared Post Hoc Test p<0.05). NR: no response.*

Do you think that this beach offers any ecosystem service?									
	Areeta^{A}		**Ereaga^{B}**		**Arrigunaga^{B}**		**Total**		**Chi-square X^2**
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Yes	39	66.1	125	83.3	62	82.7	226	79.6	8.754*
No	12	20.3	13	8.7	5	6.7	30	10.6	
NR	8	13.6	12	8.0	8	10.7	28	9.9	

Appendix B1 *– Survey on recreational fishing at Nerbioi estuary*

SECTION 1: SOCIOECONOMIC CHARACTERIZATION

1. **Gender:**

   ☐ Woman ☐ Man

2. **Age**....................years old.
3. **Post code of the village where you live nowadays**..
4. **Since when do you live in that village?** ....
5. **Which is your current employment status?**

   ☐ Employee *Profession* ………………………………………………………………………………………..

   ☐ Self-employed *Profession* ………………………………………………………………………………………..

   ☐ Unemployed. *Profession* ………………………………………………………………………………………..

   ☐ Retired. *Last* profession ……………………………………………………………………………………...

   ☐ Student

   ☐ Homemaker

   ☐ Other

6. **Completed education up-to-date:**

   ☐ None

   ☐ Primary studies

   ☐ Secondary studies

   ☐ University or higher

7. **Monthly household income (sum of all salaries at home after income-tax and social security contributions):**

   ☐ Less than 650 €/month

   ☐ 650-1.300 €/month

   ☐ 1.301-1.850 €/month

   ☐ 1.851-2.400 €/month

   ☐ 2.401-2.950 €/month

   ☐ 2.951-3.500 €/month

   ☐ 3.501-4.050 €/month

   ☐ More than 4.051 €/month

   ☐ No answer (NA)

8. **Who many people depend on that income?**

   ………..adults and ……….. < 18 years old

SECTION 2: USER vs GENERAL FISHING

9. How many years have you been practicing recreational fishing? ....years

10. Choose your MAIN MOTIVES for practicing recreational fishing. Mark a maximum of THREE and rank them from 1 to 3 (1 the most important and 3 the least important).

...... For relaxation

...... To have new or different experiences

...... To practice sport / to maintain a good physical condition

...... To practice outdoor activities

...... To be alone

..... To be with friends or relatives

...... To catch fish for eating

...... To obtain additional income

...... For the challenge of catching fish

...... To develop fishing skills

...... Other reasons. **Which?**

....

11. Do you have a recreational fishing license?

☐ Yes → **11b. Which type of license do you hold? Since when?**
- ☐ On-shore fishing. Since.................................. (year)
- ☐ Spearfishing. Since .... (year)

☐ No

☐ NA

12. How often do you practice recreational fishing? (In general, here or anywhere else).

☐ Every day or almost everyday

☐ More than once a week or every weekend

☐ Once a week

☐ Once a fortnight

☐ Once a month

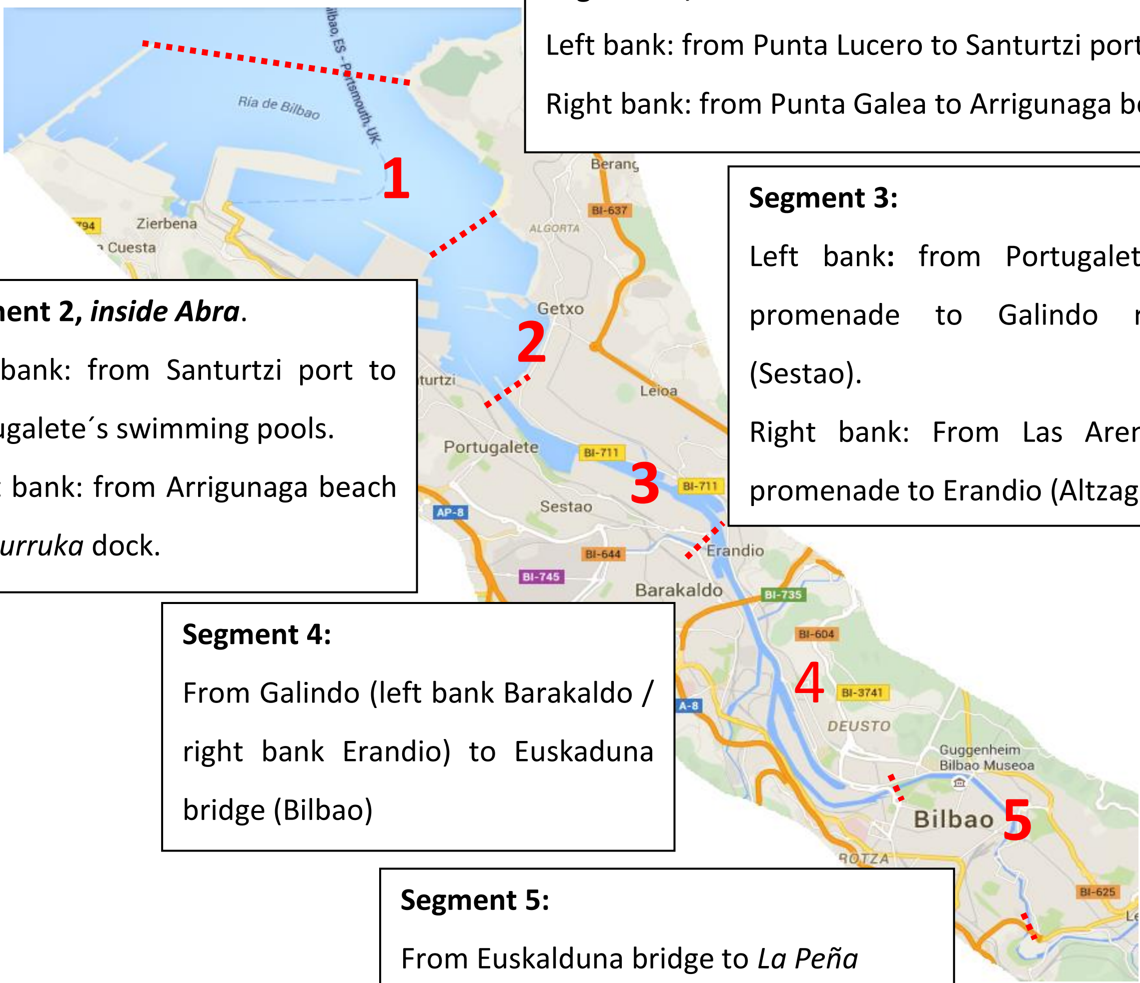
☐ Less than once a month. *How often?* ....days/year

13. How much do you invest in recreational fishing?

ANNUAL EXPENSES	FISHING DAY EXPENSES
Fishing license ....€/year Personal insurance ....€/year Fishing material (rods, fishing gear...) ....€/year Boat expenses: • License ....€/year • Mooring ....€/year • Maintenance ....€/year • Insurance ....€/year	Transport to fishing spot ....€/day Bait ....€/day Rental: • Boat ....€/day • Fishing gear ....€/day Food and beverage ....€/day Boat fuel ....€/day
OTHERS	
Any other expenses related with fishing: ....€/year ....€/year	....€/day €/day

SECTION 3. FISHING AT NERBIOI ESTUARY

Nerbioi estuary has been linked traditionally to recreational fishing. This activity is practiced from the inner Nerbioi (Bilbao) to the outer Nerbioi (the area known as *Abra* and delimited by *Punta Galea* and *Punta Lucero*).



Segment 1, *outside Abra*.

Left bank: from Punta Lucero to Santurtzi port.

Right bank: from Punta Galea to Arrigunaga beach.

Segment 2, *inside Abra*.

Left bank: from Santurtzi port to Portugalete´s swimming pools.

Right bank: from Arrigunaga beach to *Txurruka* dock.

Segment 3:

Left bank: from Portugalete´s riverside promenade to Galindo river mouth (Sestao).

Right bank: From Las Arenas Riverside promenade to Erandio (Altzaga-Desierto).

Segment 4:

From Galindo (left bank Barakaldo / right bank Erandio) to Euskaduna bridge (Bilbao)

Segment 5:

From Euskalduna bridge to *La Peña* neighbourhood (Bilbao)

We would like to know your opinion on the stretches where you have any experience fishing. Please, fill in the next tables:

SEGMENT 1: OUTSIDE ABRA

When did you fish for the first time in SEG 1?	☐ In .... (year) . ☐ I have never fished here (go to the next table)
Do you fish nowadays in SEG 1?	☐ Yes ☐ No (go to the next table)
Type(s) of fishing method(s) you practice in SEG 1	☐ From shore ☐ Spearfishing ☐ From boat
Month(s) you fish in this segment	Jn | Fb | Mr | Ap | My | Jn | Jl | Ag | Sp | Oc | Nv | Dc
Number of days you in this segment	............................days/year
In a usual fishing day, how many hours do you expend fishing in SEG 1?	....hours/fishing day

Mark on the map all the spots where you

	Species 1:	*Species 2:*	*Species 3:*
Nowadays, the most frequent species you catch are …			
Catching method (rod, spear, etc.)			
Best period to catch the species (months)			
Mean size (cm) of catches			
Mean weight (g) of catches			
Usage of the catches (mark all that apply)	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ < 5 € ☐ 6-20 € ☐ 21-35 € ☐ 36-50 € ☐ > 50 €. *How much (approx.)?* .... € ☐ NA		
Which were the most frequent species you use to catch when you started fishing in this stretch?	☐ The same species I catch nowadays (go to the next table) ☐ Others. *Which ones?*... *Why did species changed, from you point of view?*		

SEGMENT 2: INSIDE ABRA

When did you fish for the first time in SEG 2?	☐ In .... (year) ☐ I have never fished here (go to the next table)
Do you fish nowadays in SEG 2?	☐ Yes ☐ No (go to the next table)
Type(s) of fishing method(s) you practice in SEG 2	☐ From shore ☐ Spearfishing ☐ From boat
Month(s) you fish in this segment	Jn | Fb | Mr | Ab | My | Jn | Jl | Ag | Sp | Oc | Nv | Dc
Number of days you in this SEG	..............................days/year
In a usual fishing day, how many hours do you expend fishing in SEG 2?	....hours/fishing day

SEGMENT 2

Mark on the map all the spots where you

	Species 1:	Species 2:	Species 3:
Nowadays, the most frequent species you catch are ...			
Catching method (rod, spear, etc.)			
Best period to catch the species (months)			
Mean size (cm) of catches			
Mean weight (g) of catches			
Usage of the catches (mark all that apply)	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ < 5 € ☐ 6-20 € ☐ 21-35 € ☐ 36-50 € ☐ > 50 €. *How much (aprox.)?*................ € ☐ NA		
Which were the most frequent species you use to catch when you started fishing in this stretch?	☐ The same species I catch nowadays (go to the next table) ☐ Others. *Which ones?*.. *Why did species changed, from you point of view?*		

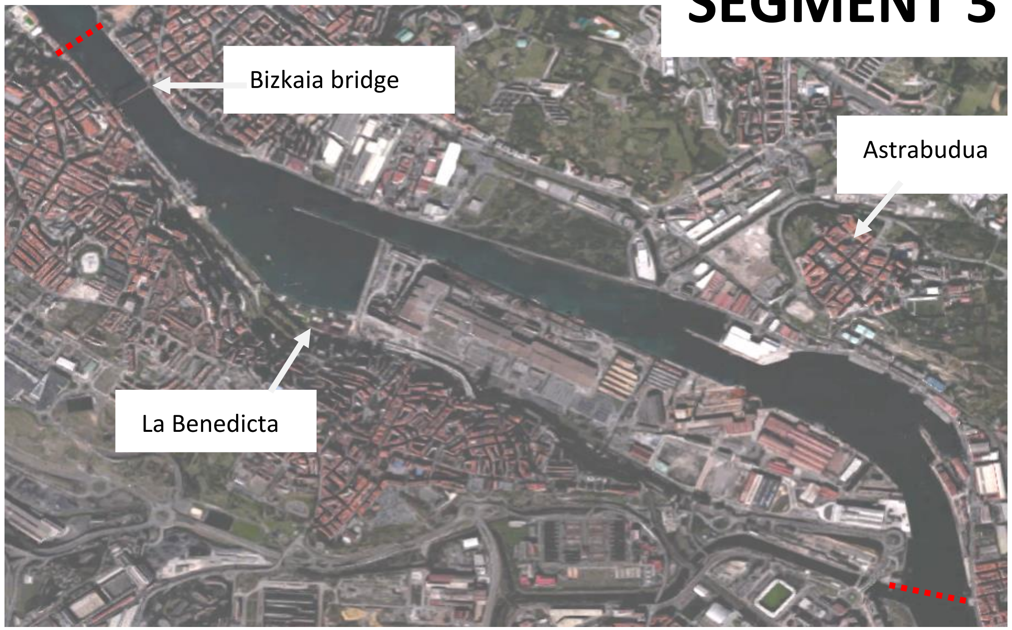
SEGMENT 3: FROM PORTUGALETE-LAS ARENAS TO GALINDO RIVER MOUTH (SESTAO-ERANDIO)

When did you fish for the first time in SEG 3?	☐ In …………… (year) ☐ I have never fished here (go to the next table)											
Do you fish nowadays in SEG 3?	☐ Yes ☐ No (go to the next table)											
Type(s) of fishing method(s) you practice in SEG 3	☐ From shore ☐ Spearfishing ☐ From boat											
Month(s) you fish in this segment	Jn	Fb	Mr	Ab	My	Jn	Jl	Ag	Sp	Oc	Nv	Dc
Number of days you in this stretch	…………………………days/year											
In a usual fishing day, how many hours do you expend fishing in SEG 3?	……………………………………… hours/fishing day											

	Species 1:	*Species 2:*	*Species 3:*
Nowadays, the most frequent species you catch are …			
Catching method (rod, spear, etc.)			
Best period to catch the species (months)			
Mean size (cm) of catches			
Mean weight (g) of catches			
Usage of the catches (mark all that apply)	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ < 5 € ☐ 6-20 € ☐ 21-35 €	☐ 36-50 € ☐ > 50 €. *How much (approx.)?* ……………. €	☐ NA
Which were the most frequent species you use to catch when you started fishing in this stretch?	☐ The same species I catch nowadays (go to the next table) ☐ Others. *Which ones?*………………………………………… *Why did species changed, from you point of view?* …………………………………………………………………… ……………………………………………………………………		

Mark on the map all the spots where you fish

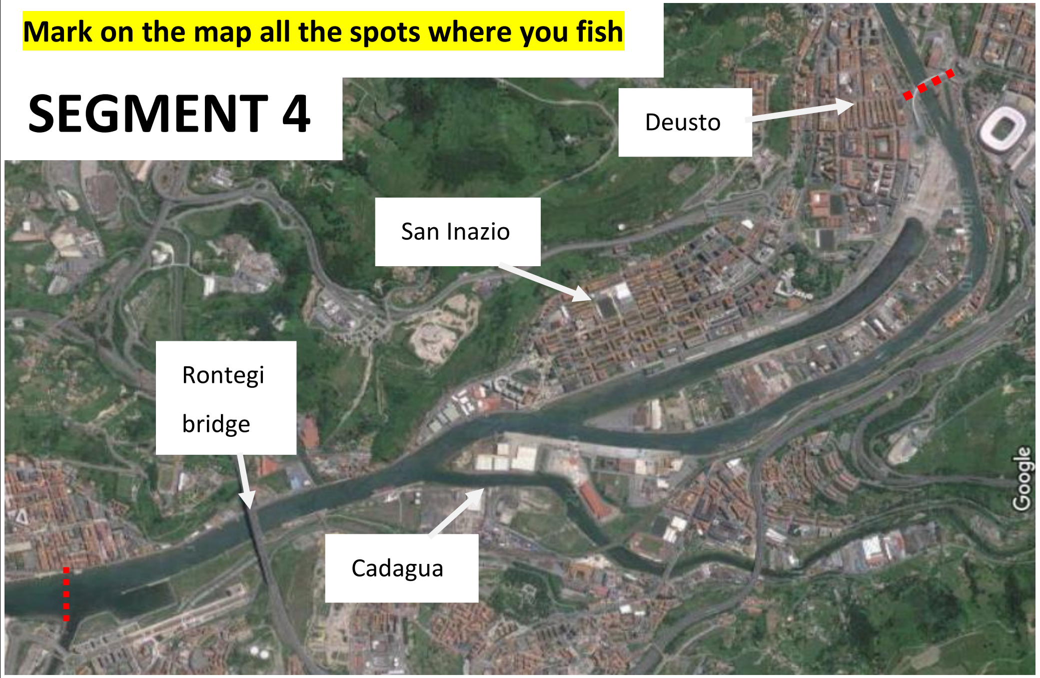
SEGMENT 3



SEGMENT 4: FROM GALINDO RIVER MOUTH (BARAKALDO-ERANDIO) TO EUSKALDUNA BRIDGE

When did you fish for the first time in SEG 4?	☐ In .... (year)					☐ I have never fished here (go to the next table)						
Do you fish nowadays in SEG 4?	☐ Yes					☐ No (go to the next table)						
Type(s) of fishing method(s) you practice in SEG 4	☐ From shore			☐ Spearfishing				☐ From boat				
Month(s) you fish in this stretch	Jn	Fb	Mr	Ab	My	Jn	Jl	Ag	Sp	Oc	Nv	Dc
Number of days you in this stretch	.............................days/year											
In a usual fishing day, how many hours do you expend fishing in SEG 4?	....hours/fishing day											

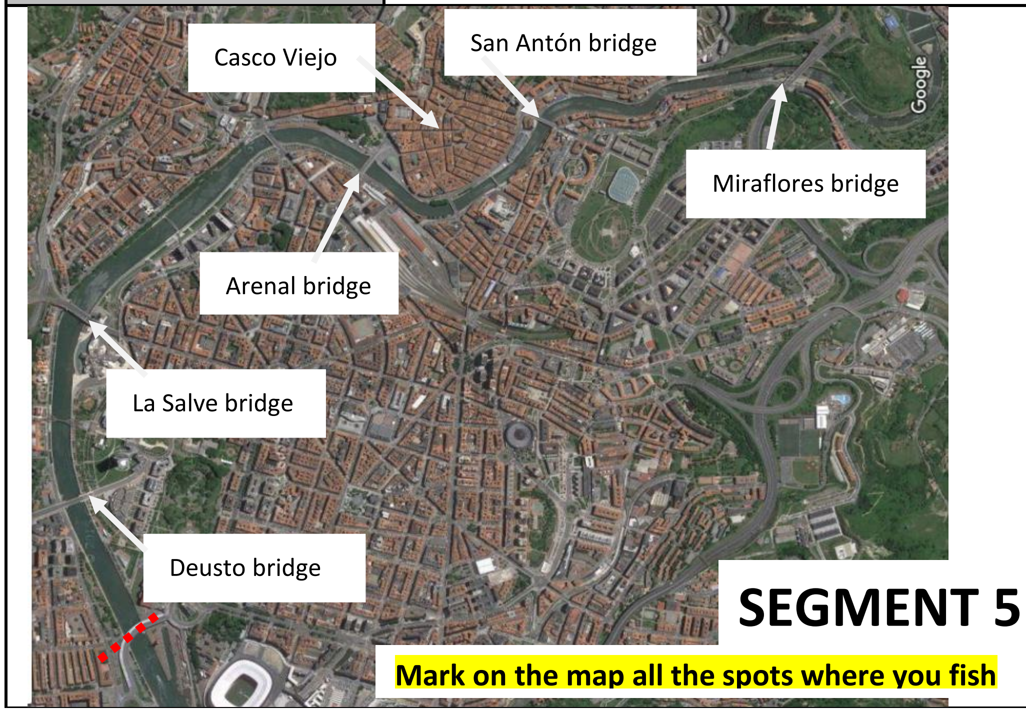
Mark on the map all the spots where you fish



Nowadays, the most frequent species you catch are ...	*Species 1:*	*Species 2:*	*Species 3:*
Catching method (rod, spear, etc.)			
Best period to catch the species (months)			
Mean size (cm) of catches			
Mean weight (g) of catches			
Usage of the catches (mark all that apply)	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ < 5 € ☐ 6-20 € ☐ 21-35 €	☐ 36-50 € ☐ > 50 €. *How much (approx.)?* .... € ☐ NA	
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ The same species I catch nowadays (go to the next table) ☐ Others. *Which ones?*... *Why did species changed, from you point of view?*		

SEGMENT 5: FROM EUSKALDUNA BRIDGE TO LA PEÑA NEIGHBOURHOOD

When did you fish for the first time in segment 5?	☐ In …………… (year) ☐ I have never fished here (go to question nº 15)
Do you fish nowadays in SEg5?	☐ Yes ☐ No (go to question nº 15)
Type(s) of fishing method(s) you practice in segment 5	☐ From shore ☐ Spearfishing ☐ From boat
Month(s) you fish in this stretch	Jn | Fb | Mr | Ab | My | Jn | Jl | Ag | Sp | Oc | Nv | Dc
Number of days you in this stretch	…………………………days/year
In a usual fishing day, how many hours do you expend fishing in stretch 5?	………………………………………hours/fishing day



	Species 1:	*Species 2:*	*Species 3:*
Nowadays, the most frequent species you catch are …			
Catching method (rod, spear, etc.)			
Best period to catch the species (months)			
Mean size (cm) of catches			
Mean weight (g) of catches			
Usage of the catches (mark all that apply	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale	☐ Release ☐ Consumption ☐ Present ☐ Sale
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ < 5 € ☐ 6-20 € ☐ 21-35 € ☐ 36-50 € ☐ > 50 €. *How much (aprox.)?*................ € ☐ NA		
Think on what your catches are in this stretch in a usual fishing day. If you had to buy it in the market instead, how much would cost you?	☐ The same species I catch nowadays ☐ Others. *Which ones?*.. *Why did species changed, from you point of view?* ……………………………………………… ………………………………………………		

15. **From all the Nerbioi segments where you have experience fishing, which one is your favourite?**

☐ SEG 1 ☐ SEG 2 ☐ SEG 3 ☐ SEG 4 ☐ SEG 5

15a. Why? ....

16. **From the most frequent species in Nerbioi, which one do you prefer catching?**

....

17. **From all the days you practice fishing, how many days do you fish at Nerbioi?**
    - ☐ Every day (I only fish at Nerbioi)
    - ☐ Nearly every day I practice fishing, I do it at Nerbioi
    - ☐ Half of the days I practice fishing, I do it at Nerbioi
    - ☐ I hardly ever fish at Nerbioi
    - ☐ NA

SECTION 4: CHARACTERIZATION OF THE FISHING DAY

18. **Did you fish today in Nerbioi?**
    - ☐ Yes → **18B. In which segment?** Segment nº........................ **18C. In images on question 14, mark with an O the fishing spot where you have fished today**
    - ☐ No (go to question 26)

19. **From where did you arrive to the fishing spot today?**
    - ☐ From home (habitual residence)
    - ☐ From work. *Which town?* ....
    - ☐ Other. *Which town?* ....

20. **Which transport did you use to arrive to the fishing spot today?**
    - ☐ Car
    - ☐ Foot
    - ☐ Bike
    - ☐ Public transport. *Which?* ....
    - ☐ Other. *Which?*..........................

21. **How long did it take you to arrive to the fishing spot?** ....minutes

22. **For how long are you planning to fish today?** ....hours

23. **Why did you choose to fish here today? Mark 3 reasons (maximum) and rank them from 1 to 3 (1 the most important and 3 the least important).**

...... It is a habit
...... Close to home / work
...... It is easy to arrive here
...... Good catches
...... Friends / Family
...... To catch (a) specific species. *Which one(s)?* ....
...... Other. *Which?* ....

24. **TYPE(S) and METHOD(S) of fishing you practiced today. Mark all the ones that apply.**

A. Type of fishing
- ☐ From shore
- ☐ Spearfishing
- ☐ From motorboat
- ☐ From boat without motor

B. Fishing method
- ☐ Casting
- ☐ Spin fishing
- ☐ Surf fishing (from beach)
- ☐ Jigging
- ☐ Trolling boats
- ☐ Spear fishing
- ☐ Other techniques without rod. *Which?* ....

25. Assess your general satisfaction with the fishing experience today.

Completely satisfied | Satisfied | Little satisfied | Unsatisfied | No answer

25b. Why are you little or not satisfied? Mark all that apply.

- ☐ Due to the scarce catches
- ☐ Fishing gear harmed
- ☐ Due to the low quality of catches
- ☐ The water is dirty
- ☐ Due to the weather
- ☐ There are too many fishers
- ☐ Other. *Why?* ……………………….

SECTION 5: PERCEPTION OF CHANGES AND GENERAL VALUATION OF THE ESTUARY

26. From the first time you fished in the estuary, did the following characteristics change? For each case, mark the box you agree the most.

From the first time you fished at Nerbioi estuary …

	Highly increased	Increased	Did not change	Decreased	Highly decreased	No answer
…the number of fishers ...						
…the number of catches on a fishing day...						
… the variety of species you catch…						
…the size of the fishes you catch…						
… the quality of the fishes you catch …						
…the number of accidental catches of marine debris…						
…the general value of the estuary for recreational fishing…						
…water quality…						
…. your personal satisfaction with fishing in the estuary …						

If you answer that the water quality has changed, in which characteristics do you notice the change?
………

If you answer that your satisfaction has changed, why did it change?
………

27. Which characteristics are important for you to enjoy fishing? How do you perceive the condition of those characteristics at Nerbioi estuary? For each characteristic, mark with an X the corresponding boxes for (i) general importance and (ii) the perceived condition at Nerbioi:

	(i) IMPORTANCE FOR THE ENJOYMENT OF FISHING ACTIVITY					(ii) PERCEIVED CONDITION IN THE NERBIOI ESTUARY				
	Essential	Important	Of little importance	Not important	NA	Excellent	Good	Average	Bad	NA
Proximity to home										
Accessibility to the fishing spot										
Calmness of the area / Tranquillity										
General cleanliness of the area										
Water transparency										
Absence of marine debris										
Absence of foam in the water										
Absence of oils in the water										
Absence of disgusting water odours										
Absence of residual discharges nearby										
Delimitation of the fishing area										
Controls to recreational fishers										
Controls of catches to recreational fishers										
Absence of numerous fishers nearby										
Absence of numerous boats nearby										
Absence of numerous people practicing aquatic sports nearby										
Numerous catches										
Great size of catches										
Great diversity of catches										
Catches with food interest										

28. In 1979, the local water authority *Consorcio de Aguas de Bilbao-Bizkaia*, initiated the Integral Sanitation Plan of Bilbao´s metropolitan area. Since then, more than 1,000 million € have been invested in the recovery of Nerbioi estuary and surrounding areas. Do you believe that the sanitation plan has favoured the recreational fishing in the estuary?

- ☐ No, the sanitation plan has not favoured recreational fishing.
  ➔ *Why?* ……………………………………………………………………………………………………
- ☐ Yes, the sanitation plan has favoured recreational fishing.
  ➔ *In which sense?* ……………………………………………………………………………………
- ☐ NA

29. Will you fish again at Nerbioi estuary?

Not probable	Rarely probable	Probably	Sure	No answer

¡THANKS FOR YOUR COLABORATION!
If you wish to receive the result of this study, please write bellow your email or your postal address and we will send you a brief report.

……

Do you want to make any suggestion or give us feedback? Please write bellow:

……

……

azti tecnalia

Txatxarramendi ugartea z/g
48395 Sukarrieta, Bizkaia

Herrera Kaia, Portualdea z/g
20110 Pasaia, Gipuzkoa

Astondo Bidea, Edificio 609
Parque Tecnológico de Bizkaia
48160 Derio, Bizkaia

Appendix B Table 1 - *Simple linear regression for the temporal trends in environmental variables, split by segments. Key: Coeff: coefficient of the regression; SE: Standard Error for the regression coefficient. Significance levels are indicated as: *p<0.05; **p<0.01; ***p<0.001.*

	SEG1		**SEG2**		**SEG3**		**SEG4**		**SEG5**	
	Coeff (SE)	**R^2**	**Coeff (SE)**	**R^2**	**Coeff (SE)**	**R^2**	**Coeff (SE)**	**R^2**	**Coeff (SE)**	**R^2**
1 O_2 surface (%)	0.40 (0.30)	0.08	0.38 (0.05)	0.73***	0.57 (0.12)	0.66***	0.33 (0.09)	0.51**	0.21 (0.09)	0.21*
2 O_2 bottom (%)	0.34 (0.40)	0.04	0.75 (0.21)	0.39**	0.76 (0.19)	0.58**	0.40 (0.09)	0.64***	0.28 (0.08)	0.39**
3 NH_4 surface (µmol l^{-1})	-0.43 (0.13)	0.38**	-0.11 (0.02)	0.54***	-0.07 (0.04)	0.20	-0.23 (0.12)	0.24	-0.11 (0.02)	0.55***
4 Fish abundance (Ind Ha^{-1})	0.01 (0.01)	0.06	0.00 (0.00)	0.09	0.00 (0.00)	0.00	0.01 (0.00)	0.45***	0.01 (0.00)	0.81***
5 Fish richness	0.72 (0.81)	0.04	1.84 (0.26)	0.66***	1.63 (0.36)	0.45***	1.81 (0.23)	0.75***	0.84 (0.12)	0.71***

Appendix B Table 2 - *Distribution of interviews in situ. Key: Samplings - number of sampling events; Total anglers - Σ[(Number of anglers when arriving to a fishing spot + Number of anglers fishing when leaving a fishing spot)]/2; Average anglers site^{-1} visit^{-1} - Total anglers/ samplings; Survey trials - number of fishers approached; Completed questionnaires - anglers who completed the questionnaire; Sampling success - completed questionnaires/samplings; Coverage (%) - completed surveys/total anglers;* ***SEG*** *– segments of the estuary, SEG1 and SEG2 are located in the outer part and SEG3, SEG4 and SEG5 in the inner part.*

	SEG1	**SEG2**	**SEG3**	**SEG4**	**SEG5**	**TOTAL**
Visited fishing spots	1	4	4	4	1	14
Samplings	5	18	12	11	5	51
Total anglers	29.5	149.5	29.5	13	7	228.5
Average anglers site^{-1} visit^{-1}	5.9	8.3	2.5	1.2	1.4	4.5
Survey trials	16	55	18	9	3	101
Completed questionnaires	14	53	18	8	3	96
Sampling success	2.8	2.9	1.5	0.7	0.6	1.9
Coverage (%)	47.5	35.4	61.0	61.5	42.9	42.0

Appendix B Table 3 - *Proxy for abundance of fish species based in the frequency with which respondents mentioned fishing each species at present (PRESENT: 146 respondents) and when they began fishing in the Nerbioi (PAST: 50 respondents), for each segment.* ***SEG*** *– segments of the estuary, SEG1 and SEG2 are located in the outer part and SEG3, SEG4 and SEG5 in the inner part.*

	PRESENT						**PAST**					
	SEG1 n=73	**SEG2** n=107	**SEG3** n=62	**SEG4** n=25	**SEG5** n=9	**TOTAL** n=146	**SEG1** n=21	**SEG2** n=27	**SEG3** n=12	**SEG4** n=8	**SEG5** n=1	**TOTAL** n=50
Diplodus vulgaris	30	68	35	18	2	**95**	5	7	3	1	1	**12**
Dicentrarchus labrax	30	48	37	23	2	**84**	6	3	1	3	1	**13**
Sepia officinalis	15	27	7			**39**						
Sparus aurata	10	21	13	9		**36**	4	3				**6**
Trachurus trachurus	21	26	2			**36**	5	3	1			**8**
Loligo vulgaris	19	24	6			**35**	1	1				**2**
Mullus surmuletus	3	17	20	1		**29**	3	3		1		**6**
Scomber scombrus	17	2				**18**	1	1				**2**
Solea solea		2	10	8		**17**	1	1		1		**3**
Diplodus sargus	8	8	3	2		**12**		1		1		**2**
Lithognathus mormyrus	2	5	5	2		**11**			1	1		**1**
Pagellus erythrinus	3	9	7	1		**11**	1	1	1			**3**
Chelon labrosus	1	2	3		6	**9**		2				**2**
Anguilla anguilla			1	3	3	**7**		1	2			**2**
Cyprinus carpio					6	**6**						
Labrus bergylta	5	4	1			**6**						
Scorpaena scrofa	1	5	1			**6**						
Serranus spp.	7	1				**6**	1					**1**
Platichthys flesus	1	2	3			**5**						
Diplodus puntazzo		1	1	2		**4**			1			**1**
Barbus bocagei					3	**3**						
Coris julis	3					**3**	1					**1**
Octopus vulgaris	3					**3**	1					**1**
Conger conger	2					**2**	1					**1**
Engraulis encrasicolus		2				**2**						
Gobius niger	1		1			**2**						
Boops boops			1			**1**						
Pagelus acarne			1			**1**						
Pagelus bogaraveo			1			**1**	3	5	1			**8**
Pollachius pollachius	1					**1**		1				**1**
Thunnus alalunga	1					**1**						
Scomberomorus cavalla	1					**1**						
Belone belone							1					**1**
Spondyliosoma cantharus								1	1			**1**
Trisopterus luscus							3	3				**4**
Dentex dentex								1				**1**

Appendix C Protocol - *Statistical data treatment to determine the best regressions for fish abundance and fish richness*

As fish abundance and richness were selected as the output variables of the ecological sub-model, first, individual regressions were built up with each of the independent variables (i.e. 25 biotic and abiotic variables measured in the estuary, see also Appendix Table A.1). Fish abundance data were log-transformed. For fish richness data, a mean value for the whole estuary was calculated as: the total number of different species present in the five sampling transects in the same year. Linear models were chosen for log-fish abundance and Poisson regression models for fish richness, as these are count data (Zuur *et al.*, 2007). The independent variables that showed non-significant relation on the regression models with the dependent variables were definitively removed from the analysis.

To ensure that there was no multicollinearity among the independent variables, the variance inflation factor (VIF) technique was used (Zuur *et al.*, 2010). Two VIF analysis were performed, one which each group of the independent variables selected in the previous step and for each of the dependent variables. The independent variable with the highest VIF value was removed sequentially, running the two VIF analysis until all the variables had a VIF<3.

For each of the two dependent variables, the model with the lowest Akaike Information Criterion value was selected, using the MuMIn package (Barton, 2016). If the selected model contained any explanatory variable with non-significant influence, this variable was removed until all the variables included had a significant influence.

The statistical treatment was performed in two different stages: first, with all the samples available, and secondly, only with samples that have the oxygen saturation higher than 80%. The second analysis allowed to check if once oxygen is no longer a limiting factor, other variables could be having a significant effect on fish abundance and richness.

Once the relations between fish abundance and richness with biotic and abiotic variables were stablished for the estuary, the relationships between estuary and tributary variables were explored. In this case, the objective was to check if the concentration of certain variables in the estuary were related with the concentration of the same variable measured in the two tributaries. For the ammonium concentration, in addition to the relationship between concentration in the estuary and concentration in tributaries, the relationship with WWTP ammonium loads was explored.

Appendix C Table 1 - *Resume of the biotic and abiotic variables analyzed to check if they were related to fish abundance and fish richness. For some variables, the sampling frequency has changed along the sampling period; the frequency indicated as sampling frequency corresponds to the current one. Key: CABB: Bilbao-Bizkaia Water Consortium, URA: Basque Water Agency; B: bottom; S: surface.*

	Variables	Unit	Sampling stations	Origin	Sample type	Depth	Sampling frequency	Data period	Notes
Estuary									
Fish	Fish abundance	Ind Ha^{-1}	5	CABB	Fish trawl	B	yearly	1989-2015	
	Fish richness	Nº species	5	CABB	Fish trawl	B	yearly	1989-2015	
Phytoplankton	Phytoplankton diversity	bit cel^{-1}	8	CABB	Phytoplankton	S	quarterly	2002-2015	Only samples from May to October were used to calculate the year mean
	Phytoplankton abundance	cel l^{-1}	8	CABB	Phytoplankton	S	quarterly	2002-2015	
	Mean chlorophyll a concentration	µg l^{-1}	5	URA	Phytoplankton	S	quarterly	1995-2015	
Sediment	Benthic invertebrates (richness)	Nº species	6	CABB	Sediment	Sed	yearly	1989-2015	
	Benthic invertebrates (abundance)	Ind m^{-2}	6	CABB	Sediment	Sed	yearly	1989-2015	
	Organic matter in the sediment	%	5	URA	Sediment	Sed	yearly	1995-2015	
Water	Salinity	USP	8	CABB	Water	S/B	monthly	1990-2015	
	Temperature in the water	°C	8	CABB	Water	S/B	monthly	1990-2015	
	Total Phosphorous	mg l^{-1}	5	URA	Water	S	quarterly	1995-2015	
	Total Nitrogen	mg l^{-1}	5	URA	Water	S	quarterly	1995-2015	
	Turbidity	NTU	5	URA	Water	S	quarterly	1995-2015	
	Suspended solids	mg l^{-1}	5	URA	Water	S	quarterly	1995-2015	
	Dissolved oxygen	mg l^{-1}	8	CABB	Water	S/B	monthly	1990-2015	
	Oxygen saturation	%	8	CABB	Water	S/B	monthly	1990-2015	
	Ammonium	µmol l^{-1}	8	CABB	Water	S	monthly	1990-2015	
	Zinc	µg l^{-1}	5	URA	Water	S	quarterly	1994-2015	Quarterly in 2 stations, yearly in 3 stations
	Lead	µg l^{-1}	5	URA	Water	S	monthly	1994-2015	Monthly in 2 stations, yearly in 3 stations
	Cadmium	µg l^{-1}	5	URA	Water	S	monthly	1994-2015	Monthly in 2 stations, yearly in 3 stations
	Silicate	mg l^{-1}	5	URA	Water	S	quarterly	1994-2015	
	Nitrate	mg l^{-1}	5	URA	Water	S	quarterly	1994-2015	
	Nitrite	mg l^{-1}	5	URA	Water	S	quarterly	1994-2015	
	Orthophosphate	mg l^{-1}	5	URA	Water	S	quarterly	1994-2015	
Derived	O_2 mean saturation	%						1990-2015	Station monthly mean
	N/P ratio	-						1995-2015	Station quarterly mean
	Fish richness (mean)	Nº species						1989-2015	Estuary annual mean

	Variables	Unit	Sampling stations	Origin	Sample type	Depth	Sampling frequency	Data period	Notes
Tributaries									
Water	Ammonium	µmol l^{-1}	2	CABB	Water	S	year mean	1990-2014	
	Zinc	µg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Lead	µg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Cadmium	µg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Silicate	mg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Nitrate	mg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Nitrite	mg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	
	Orthophosphate	mg l^{-1}	4	URA	Water	S	7-12 samples yearly	1993-2015	

Appendix C Table 2 - *Summary of the variables included in the final SDM for recreational fishing in Nerbioi.*

Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Ecological sub-model							
Auxiliar	Cadmium concentration estuary	Estimated mean cadmium concentration in 2011, calculated with the regression for the period (2002-2015)	CdE		0.161	µg l^{-1}	This study, estimated with URA data
Auxiliar	Cadmium impact on fish	Smoothed cadmium concentration in the estuary, considering that after a change in Cd concentration fish abundance will need an additional time to recover	CdF	DELAY1(CdE - 0.161, TDCd) * 2 + 0.161		µg l^{-1}	This study
Auxiliar	Constant NH_4 Ibaizabal-Nerbioi load	Total ammonium load spilled to the estuary from Ibaizabal-Nerbioi	IbaNH4L	(NH4Iba * WIba) / 10^6		Mol $Month^{-1}$	CABB, estimated with URA data
Auxiliar	Constant NH_4 Kadagua load	Total ammonium load spilled to the estuary from Kadagua	KadNH4L	(NH4Kad * WKad) / 10^6		Mol $Month^{-1}$	CABB, estimated with URA data
Auxiliar	Estuarine area	Recalculated with GIS layers	Earea		2035	Ha	This study, estimated with GEOEuskadi
Auxiliar	Fish abundance	Mean fish abundance in the estuary	FABD	O2<80%: EXP (-0.6186 + 0.0644*O2E) {R^2=34.72; p-value<0.001} O2>80%: EXP (-0.20171-0.04326*ZnE-0.70554*CdE + 0.07223*O2E) {R^2=52.9; p-value<0.001}		Ind Ha^{-1}	This study, estimated with CABB data
Auxiliar	Fish richness	Number of fish species present in the estuary	FRCH	EXP (0.54047 + 0.026508*O2E) {McFadden pseudo-R^2=23.47}		nº species	This study, estimated with CABB
Auxiliar	Maximum fish population	Highest annual mean fish abundance, calculated with historical data series (1990-2015)	maxFABD		1810		This study, estimated with CABB data
Auxiliar	NH_4 secondary concentration	Ammonium concentration of the water that spills to the estuary after secondary treatment (2008-2014)	NH4SEC		51.6794	µmol l^{-1}	CABB
Auxiliar	NH_4 estuary concentration	Mean ammonium concentration at the estuary	NH4E	1.904 + WWTPNH4L*5.265e-006) + (IbaNH4L*1.388e-005) + (KadNH4L *1.684e-005) {R^2=92.52; p-value<0.001}		µmol l^{-1}	This study, estimated with CABB data
Auxiliar	NH_4 Ibaizabal-Nerbioi concentration	Mean annual ammonium concentration at the tributary (2006-2014)	NH4Iba		9.34474	µmol l^{-1}	CABB, estimated with URA data

Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Auxiliar	NH_4 Kadagua concentration	Mean annual ammonium concentration at the tributary (2006-2014)	NH4Kad		8.21829	µmol l^{-1}	CABB, estimated with URA data
Auxiliar	NH_4 primary concentration	Ammonium concentration of the water that spills to the estuary after the primary treatment (2008-2014)	NH4PRIM		1712.59	µmol l^{-1}	CABB
Auxiliar	NH_4 spillway concentration	Ammonium concentration of the water that spills to the estuary with no treatment (2008-2014)	NH4SPILL		1998.42	µmol l^{-1}	CABB
Auxiliar	NH_4 WWTP load	Total ammonium load spill to the estuary from the WWTP	WWTPNH4L	NH4SPILL · WSPILL + NH4PRIM · WPRIM + NH4SEC · WSEC / 10^6		Mol $Month^{-1}$	CABB
Auxiliar	Oxygen saturation estuary	Mean oxygen saturation at the estuary	O2E	95.47 - 0.1795 NH4E {R^2=88.39; p-value<0.001}		%	This study, estimated with CABB data
Auxiliar	Oxygen impact on fish	Smoothed oxygen saturation in the estuary, considering that after a change in O2, fish abundance and richness will need an additional time to recover	CdF	DELAY1(O2E-91.63, TDO2)*10+91.63		%	This study
Auxiliar	Time delay Cd	Time delay on recovery of fish abundance after changes in Cd concentration	TDCd		0.3332	Year	(Wright and Welbourn, 1994; Borja *et al.*, 2010a)
Auxiliar	Time delay O_2	Time delay on recovery of fish abundance after changes in O_2 saturation	TDO2		2	Year	(Uriarte and Borja, 2009; Borja *et al.*, 2010a)
Auxiliar	Time delay Zn	Time delay on recovery of fish abundance after changes in Zn concentration	TDZn		0.3332	Year	(Giardina *et al.*, 2009; Borja *et al.*, 2010a)
Auxiliar	Water inflow secondary	Water volume that spills to the estuary after secondary treatment (2008-2014)	WSEC		9,075.97 · 10^6	l $Month^{-1}$	CABB
Auxiliar	Water inflow Ibaizabal-Nerbioi river	Water volume spilled to the estuary from Kadagua (2006-2014)	WIba		54,733.2 · 10^6	l $Month^{-1}$	CABB, estimated with URA data
Auxiliar	Water inflow Kadagua river	Water volume spilled to the estuary from Kadagua (2006-2014)	WKad		26,644.4 · 10^6	l $Month^{-1}$	CABB, estimated with URA data
Auxiliar	Water inflow primary	Water volume that spills to the estuary after primary treatment (2008-2014)	WPRIM		671,401 · 10^3	l $Month^{-1}$	CABB

Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Auxiliar	Water inflow spilway	Water volume that spills to the estuary with no treatment (2008-2014)	WSPILL		$15{,}574.6 \cdot 10^3$	$l\ Month^{-1}$	CABB
Auxiliar	Zinc concentration estuary	Mean zinc concentration in 2011, calculated with the regression for the period (2002-2015)	ZnE	15.956	15.956	$\mu g\ l^{-1}$	This study, estimated with URA data
Auxiliar	Zinc impact on fish	Smoothed zinc concentration in the estuary, considering that after a change in Zn concentration fish abundance will need an additional time to recover	ZnF	DELAY1(ZnE-15.956, TDZn)*2+15.956		$\mu g\ l^{-1}$	This study
Social sub-model							
Flow	Catches	Estimation of recreational fishers´ catches	CTH	FNGABI*TRIPTOT*(GF/maxGF)		Fish $month^{-1}$	This study
Auxiliar	Accessible shoreline	Areas were fishers currently fish, calculated with ortophotos and visiting the estuary	ACS		8200	m	This study and Chapter B
Auxiliar	Space availability	Space availability per fisher and per visit	SPC	ACS/(TRIPTOT/30)		m $Fisher^{-1}$	This study
State	Active recreational fishers	From the 52,300 recreational fishing licenses in the Basque Country (2015); more than 2,300 were of fishers fishing in the outer Nerbioi (Ruiz et al. 2014). 200 fishers more were added to include those who only fish in the inner Nerbioi (Chapter B)	FISHER	±varFISHER	2500	fisher	(Ruiz *et al.*, 2014) and CHapter B
Auxiliar	Fishing ability	Mean number of catches per participant in the annual recreational fishing competition (2002-2015)	FNGABI		0.85	Catch $trip^{-1}$	This study, estimated with FBPC data
Auxiliar	Maximum gaming fish population	Highest gaming fish abundance, estimated with historical data series (1990-2015) and Chapter B	maxGF	maxFABD*Earea*prABD		Fish	This study, estimated with CABB data and Chapter B
Auxiliar	Fishers persuasion capacity	New fishers that each active recreational fisher is able to convince to start fishing in Nerbioi	perFISHER	When satisfaction <0.45	-0.1	Fisher $month^{-1}$	This study
				When satisfaction >0.55	1	Fisher $month^{-1}$	This study

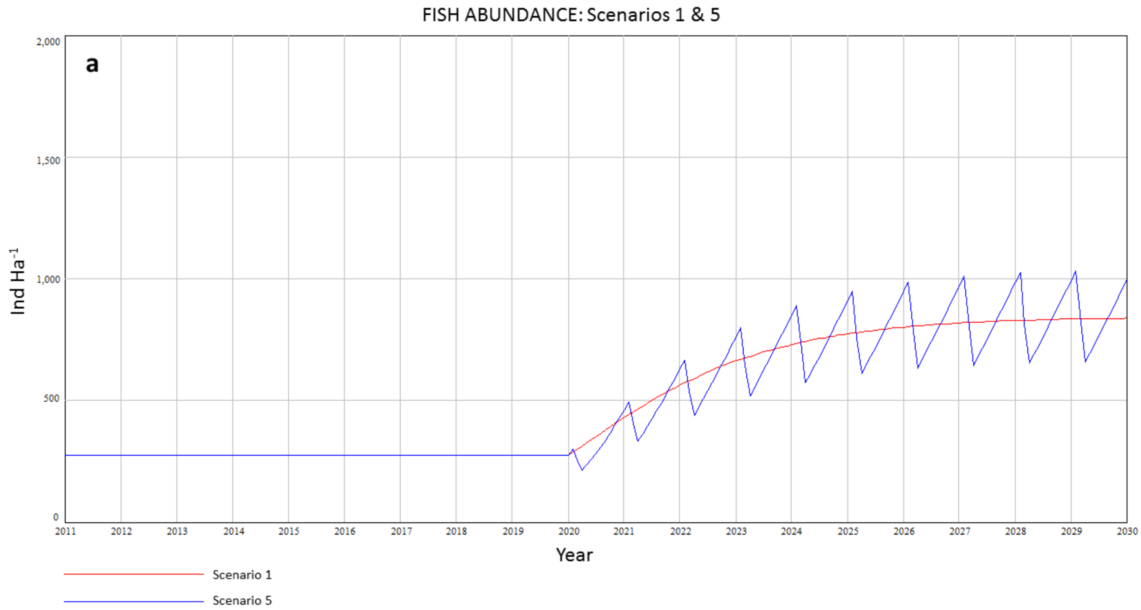
Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Auxiliar	Proportion of gaming species abundance	From the total fish abundance in CABBs annual samplings (2002-2015), the percentage that corresponded with species mentioned by fishers as regular catches in Chapter B	prABD		30	%	CABB data and Chapter B
Auxiliar	Proportion of gaming species	From the total number of species in CABBs annual samplings (2002-2015), the proportion that corresponded to species mentioned by fishers as regular catches in Chapter B	prRCH		34	%	CABB and Chapter B
State	Gaming fishes	Number of gaming fishes present in the estuary	GF	varGF-CTH	$1.07099 \cdot 10^6$	Fish	This study
Auxiliar	Gaming species richness	Number of gaming fish species present in the estuary	GFRCH	prRCH * FRCH		species	Chapter B
Auxiliar	Crowd satisfaction	Satisfaction with the space availability for fishing	satCRW	Fixed values in relation to SPC as: (0,0),(20,1),(39,2),(40,2),(60,3),(80,3),(150,2),(200,1),(250,1),(300,1)	-	*n.u.*	This study, estimated with Chapter B
Auxiliar	Trip-catch satisfaction	Satisfaction with the catches per monthly fishing trip	satCTH	Fixed values in relation to CTH/FISHER as: (0,0),(2,1),(4,3),(6,3),(20,3)	-	*n.u.*	This study, estimated with Chapter B
Auxiliar	Gaming Species Satisfaction	Satisfaction with the gaming fish species	satRCH	Fixed values in relation to GFRCH as: (0,0),(8,2),(10,3),(20,3),(50,3)	-	*n.u.*	This study, estimated with Chapter B
Auxiliar	Satisfaction ratio	Overall satisfaction, dependent on the three partial satisfactions	satTOT	0.5satCTH /DsatCTH + 0.3satCRW /DsatCRW + 0.2satRCH/DsatRCH		*n.u.*	This study
Auxiliar	Desired crowd satisfaction	Maximum possible crowd satisfaction	DsatCRW		3	*n.u.*	This study, estimated with Chapter B
Auxiliar	Desired trip-catch satisfaction	Maximum possible trip-catch satisfaction	DsatCTH		3	*n.u.*	This study, estimated with Chapter B
Auxiliar	Desired gaming species satisfaction	Maximum possible gaming species satisfaction	DsatRCH		3	*n.u.*	This study, estimated with Chapter B

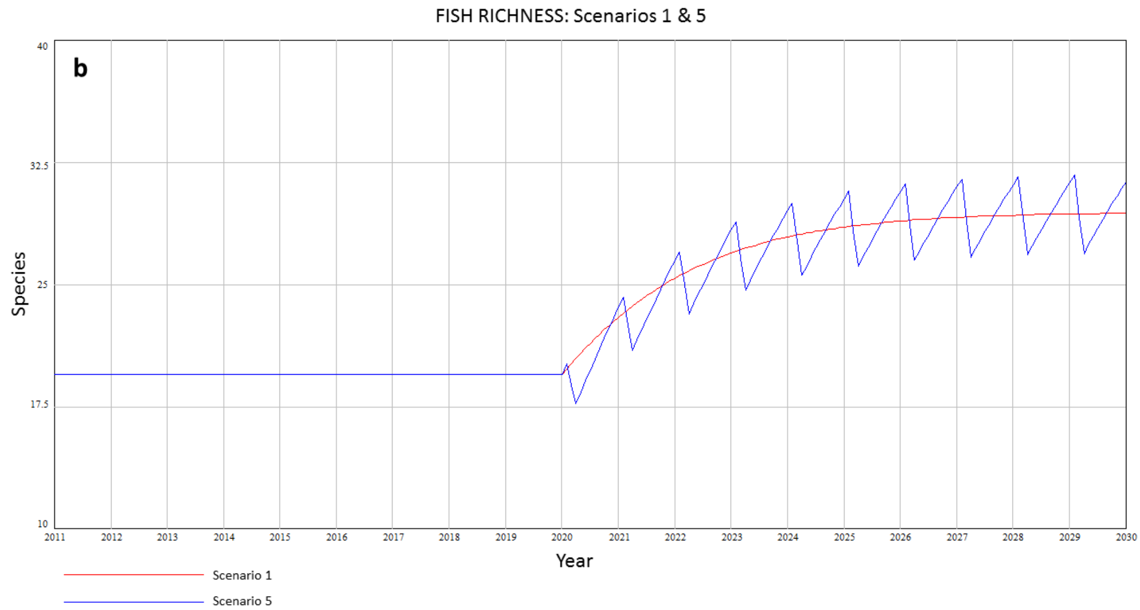
Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Auxiliar	Monthly fishing trips per fisher	Number of monthly fishing trips to the estuary that each fisher does (median)	TRIPFISHER		2.5	trip $month^{-1}$	Chapter B
Auxiliar	Total monthly fishing trips	Total number of monthly fishing trips to the estuary	TRIPTOT	FISHER*TRIPFISHER		trip $month^{-1}$	
Flow	Variation of gaming fishes	Theorical flow representing changes in gaming fish abundance	varGF	Earea*FABD*prABD*(1-GF/maxGF)		fish $month^{-1}$	This study
Flow	Fishers variation	Variation on the number of active recreational fishers	varFISHER	satTOT<0.45: varFISHER = - FISHERS * perFISHER * satTOT satTOT= 0.45 - 0.55; varFISHER = 0 WHEN satTOT>0.55: varFISHER = FISHERS * perFISHER * satTOT		fisher $month^{-1}$	This study
Variables added/changed to simulate scenario 2							
Auxiliar	Disturbance duration WWTP	Estimated duration of the WWTP failure: 2 months	DdWWTP		0.167	year	New variable
Auxiliar	WWTP damage year	Year when the failure of WWTP is simulated	WWTPdamy		2020	year	New variable
Auxiliar	Water inflow spillway	-	WSPILL	WSPILL+PULSE(WWTPdamy, DdWWTP)*(WPRIM+WSEC)	15,574.6 · 10^3	l $Month^{-1}$	Modified variable: after damage, WPRIM + WSEC added to WSPILL
Auxiliar	Water inflow primary	-	WPRIM	WPRIM - PULSE(WWTPdamy, DdWWTP)*WPRIM	671,401 · 10^3	l $Month^{-1}$	Modified variable
Auxiliar	Water inflow secondary	-	WSEC	WSEC - PULSE(WWTPdamy, DdWWTP)*WSEC	9,075.97 · 10^6	l $Month^{-1}$	Modified variable

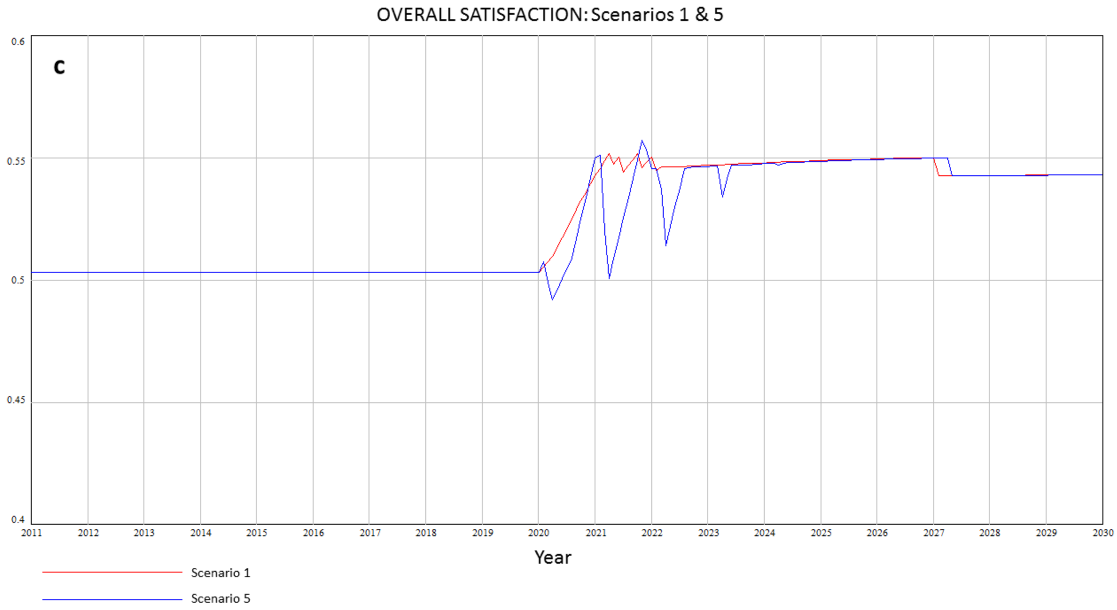
Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Variables added to simulate scenario 3							
Auxiliar	Disturbance duration Cd	Estimated duration of the disturbance on Cd concentration as a consequence of dredge works: 4 months	DdCd		0.332	year	New
Auxiliar	Disturbance duration Cd	Estimated duration of the disturbance on Zn concentration as a consequence of dredge works: 4 months	DdZn		0.332	year	New
Auxiliar	Dredging year	Year when the dredge is simulated	dredgey		2020	year	New
Auxiliar	Cadmium concentration estuary	-	CdE	0.161+PULSE(dredgey,DdCd)*0.0805		$\mu g\ l^{-1}$	Modified
Auxiliar	Zinc concentration estuary	-	ZnE	15.956+7.978*PULSE(dredgey, DdZn)		$\mu g\ l^{-1}$	Modified
Variables added to simulate scenario 4							
Auxiliar	Annual Ibaizabal Nerbioi	The annual water inflow from the Ibaizabal-Nerbioi tributary	AWIba	WIba*m		L $year^{-1}$	New
Auxiliar	Annual Kadagua	The annual water inflow from the Kadagua tributary	AWKad	WKad*m		L $year^{-1}$	New
Auxiliar	Climate Change	If the effects of climate change want to be activated =1, and =0 if not	CC		0-1		New
Auxiliar	Climate Change Ibaizabal Nerbioi load	Total ammonium load spilled to the estuary from Ibaizabal-Nerbioi, when climate change conditions are simulated	CCIbaNH4L	IbaNH4L +STEP(-IbaNH4L + (NH4Iba * RdmWIba)/ 10^6, 2020)		Mol $Month^{-1}$	New
Auxiliar	Climate Change Kadagua load	Total ammonium load spilled to the estuary from Kadagua, when climate change conditions are simulated	CCKadNH4L	KadNH4L +STEP(-KadNH4L + (NH4Kad * RdmWKad)/10^6, 2020)		Mol $Month^{-1}$	New
Auxiliar	Dry month	In a dry month (10 out of 12), the rain will be 2% of the total annual rain	dm		0.02		New
Auxiliar	Months		m		12	Month	New

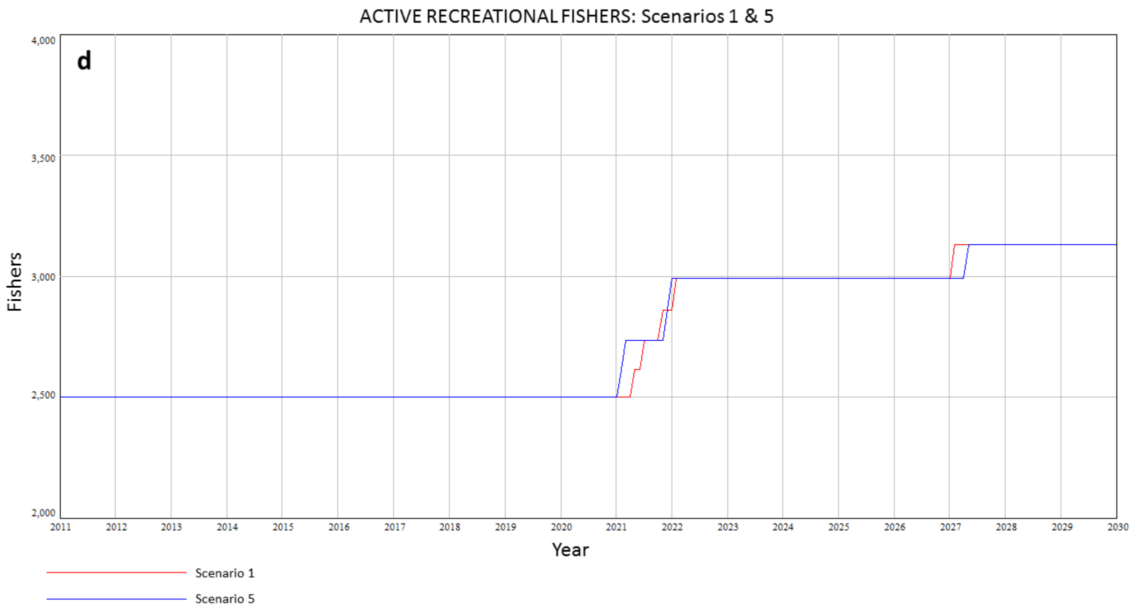
Type	Name	Explanation	Short-name	Equation	Initial value	Unit	Data source and calculation
Auxiliar	NH4 Ibaizabal-Nerbioi load	Total amount of NH4 from Ibaizabal-Nerbioi arriving to the estuary	NH4IbaL2	IF THEN ELSE(CC=0, IbaNH4L, CCIbaNH4L)		Mol $Month^{-1}$	New
Auxiliar	NH4 Kadagua load	Total amount of NH4 from Kadagua arriving to the estuary	NH4KadL2	IF THEN ELSE(CC=0, KadNH4L, CCKadNH4L)		Mol $Month^{-1}$	New
Auxiliar	Pulse water monthly Ibaizabal Nerbioi	The monthly amount of water that arrives to the estuary from the tributary, setting the rainy months to happen in February-March	pWIba	AWIba * dm + AWIba * (rm - dm) * (PULSE TRAIN (2011.08, 0.167, 1,2030))		L $month^{-1}$	New
Auxiliar	Pulse water monthly Kadagua	The monthly amount of water that arrives to the estuary from the tributary, setting the rainy months to happen in February-March	pWKad	AWKad * dm + AWKad *(rm - dm) * (PULSE TRAIN(2011.08, 0.167, 1, 2030))		L $month^{-1}$	New
Auxiliar	Rain dry month Ibaizabal Nerbioi	Total amount of water from the Ibaizabal-Nerbioi arriving to the estuary on a dry month	RdIba	AWIba * dm		L $month^{-1}$	New
Auxiliar	Rain dry month Kadagua	Total amount of water from the Kadagua arriving to the estuary on a dry month	RdKad	AWKad * dm		L $month^{-1}$	New
Auxiliar	Rainy month	In a rainy month (2 out of 12), the rain will be 40% of the total annual rain	rm		0.4		New
Auxiliar	Rain rainy month Ibaizabal Nerbioi	Total amount of water from the Ibaizabal-Nerbioi arriving to the estuary on a rainy month	RrKad	AWIba * rm		L $month^{-1}$	New
Auxiliar	Rain rainy month Kadagua	Total amount of water from the Kadagua arriving to the estuary on a rainy month	RrIba	AWKad * rm		L $month^{-1}$	New
Auxiliar	Random water inflow Ibaizabal Nerbioi	In climate change conditions, water running monthly on Ibaizabal-Nerbioi	RdmWIba	RANDOM NORMAL(RdIba, RrIba, pWIba, 100, 20)		L $month^{-1}$	New
Auxiliar	Random water inflow Kadagua	In climate change conditions, water running monthly on Kadagua	RdmWKad	RANDOM NORMAL(RdKad, RrKad, pWKad, 100, 20)		L $month^{-1}$	New

Appendix C Figure 1 - *Fish abundance (a), fish richness (b), overall satisfaction (c) and number of active recreational fishers (d) in Scenario 1 (marine outfall scenario) and Scenario 5 (marine outfall & climate change).*

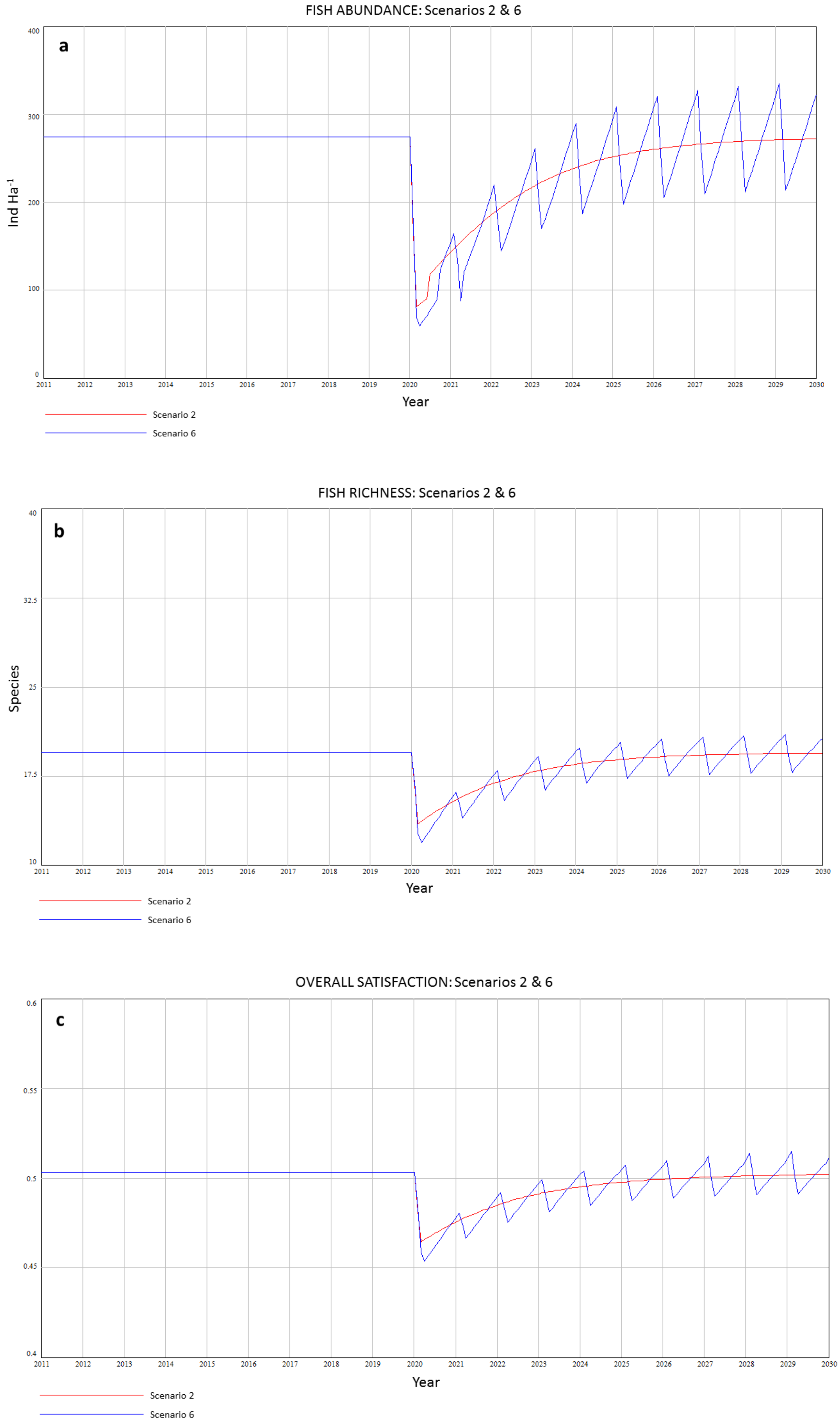




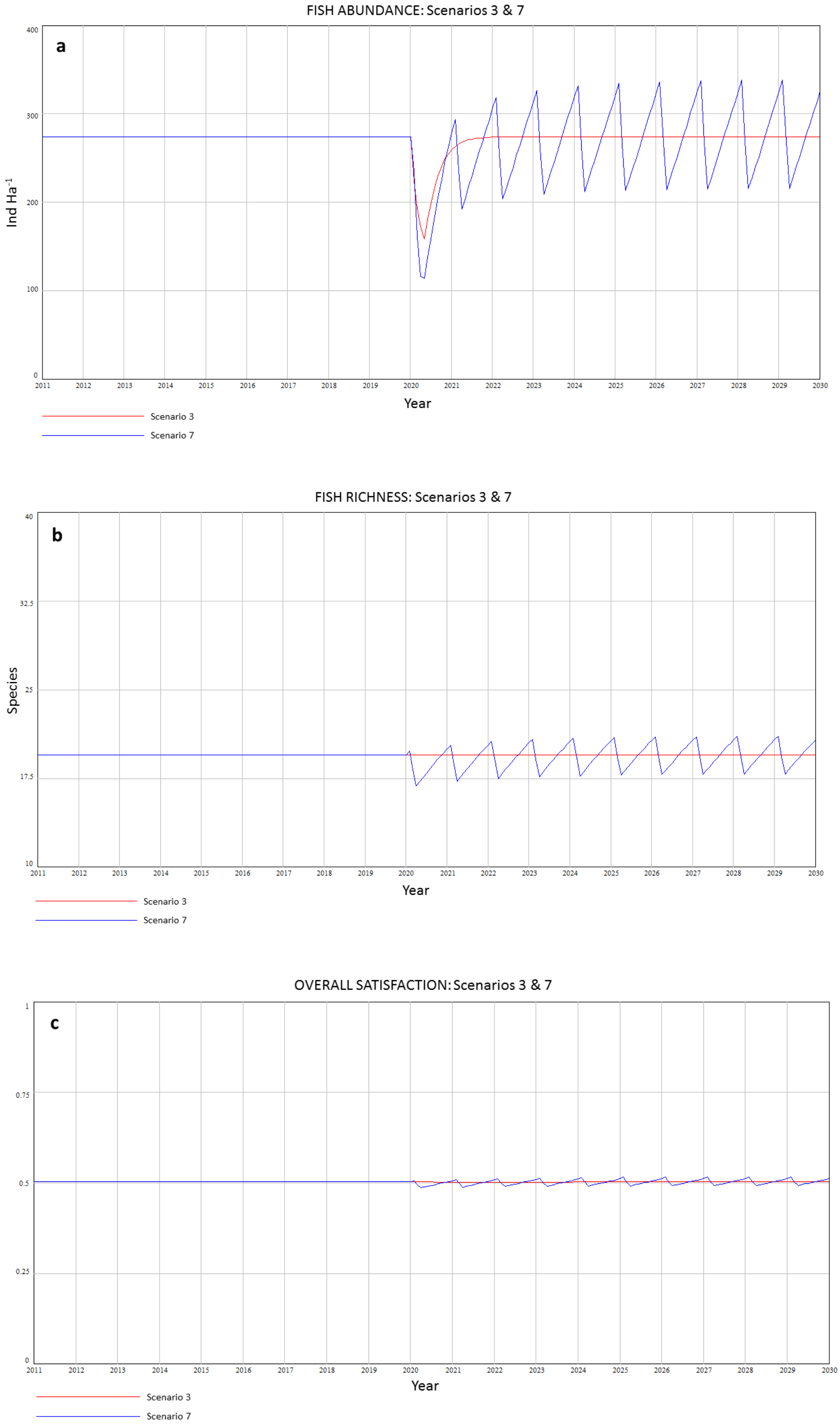

OVERALL SATISFACTION: Scenarios 1 & 5
c
0.6
0.55
0.5
0.45
0.4
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year
Scenario 1
Scenario 5


ACTIVE RECREATIONAL FISHERS: Scenarios 1 & 5
d
Fishers
4,000
3,500
3,000
2,500
2,000
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year
Scenario 1
Scenario 5

Appendix C Figure 2 - *Fish abundance (a), fish richness (b) and overall satisfaction (c) in Scenario 2 (WWTP failure) and Scenario 6 (WWTP failure & climate change).*



Appendix C Figure 3 - *Fish abundance (a), fish richness (b) and overall satisfaction (c) in scenario 3 (dredge) and scenario 7 (dredge & climate change).*



Appendix D Table 1 - *Basic Poisson models for Nerbioi beaches. Key: TC: Travel Cost; TCS: Travel cost to substitute site; ***: p-value<0.001; **: p-value<0.01; *: p-value<0.05; n.s.: not significant.*

	Areeta				**Ereaga**				**Arrigunaga**			
	Coefficient	**Std. Error**	**z value**		**Coefficient**	**Std. Error**	**z value**		**Coefficient**	**Std. Error**	**z value**	
(Intercept)	3.665	0.075	48.792	***	3.327	0.041	81.287	***	4.093	0.079	51.72	***
TC	-0.041	0.017	-2.364	*	-0.127	0.015	-8.741	***	-0.14	0.016	-8.719	***
TCS	-0.047	0.022	-2.088	*	0.083	0.013	6.203	***	0.071	0.021	3.317	***
***Income* (655.2 -1394.93€)**	-0.031	0.063	-0.485	n.s.	0.071	0.039	1.818	n.s.	-0.724	0.07	-10.346	***
***Income* (> 1394.93€)**	0.044	0.063	0.699	n.s.	0.228	0.043	5.313	***	-0.527	0.069	-7.627	***
Observations	93				209				98			
McFadden pseudo R^2	0.145				0.15				0.143			

Appendix D Table 2 - *Correlation results between demographic variables and Travel Cost, Travel Cost to the Substitute and Income. Key: TC: Travel Cost; TCS: Travel cost to substitute site; I: Income; ρ: Spearmans' rank correlation test; U: Mann-Whitney U Test;* X^2*: Chi squared analysis; n.s.: not significant (p-value>0.05).*

Variables	**TC**			**TCS**			**I**		
	Statistical Test		**p-value**	**Statistical Test**		**p-value**	**Statistical Test**		**p-value**
Age	ρ	-0.214	0.031	ρ	-0.211	0.042	ρ	0.264	<0.001
Gender	*U*	13,312	0.026	*U*	13,706	n.s.	X^2	1.894	*n.s.*
Education	*U*	24,106	0.002	*U*	24,852	<0.001	X^2	7.398	0.025
Employment	*U*	18,456	n.s.	*U*	18,313	n.s.	X^2	10.404	0.006
Origin	ρ	0.712	<0.001	ρ	0.657	<0.001	ρ	-0.331	<0.001
Beach time	ρ	0.275	<0.001	ρ	0.310	<0.001	ρ	-0.148	*n.s.*
Company	*U*	16,520	n.s.	*U*	17,562	n.s.	X^2	3.352	*n.s.*
Aquatic sports	*U*	21,112	n.s.	*U*	21,108	n.s.	X^2	1.846	*n.s.*
Overall satisfaction	*U*	4,334	n.s.	*U*	4,724	n.s.	X^2	0.929	*n.s.*
Seasons coming	ρ	-0.307	<0.001	ρ	-0.258	<0.001	ρ	0.180	*n.s.*

Appendix E Table 1 - *Income, demographic and fishing trends among recreational fishers in Nerbioi.*

Variable	Description	Type	Categories	n	%	Mean	SD	min	max
Income and demographics									
Income	Monthly income. Ranks were fixed according to minimum wage in Spain and the mean wage in the estuarine towns in 2016	Categorical (rank)	<= 655	35	36				
			655-1408	52	53				
			>1408	11	11				
Age	Age of the respondents	Continuous				52	15	18	90
Gender	Gender of the respondent	Dichotomous	Male	94	96				
			Female	4	4				
Education	Maximum education achieved by the respondent	Categorical	Primary or less	57	58				
			Secondary	38	39				
			High education	3	3				
Employment	Employment status of the respondent	Categorical	Employed / self employed	36	37				
			Unemployed	19	19				
			Retired	40	41				
			Others	3	3				
Origin	Hometown of the respondent	Categorical	Estuarine villages	89	91				
			Other villages in the region	9	9				
Fishing in Nerbioi									
Transport	Transport used to reach the estuary		Car	65	66				
			Walking	17	17				
			Bike	1	1				
			Public transport	12	12				
			Others	3	3				
Fishing activity by SEG	Number of respondents fishing nowadays in each SEG (n & %) and mean number of days that active fishers' fish in each SEG	Categorical	SEG1	46	47	65	82	2	365
			SEG2	75	77	78	83	2	365
			SEG3	41	42	80	92	2	300
			SEG4	17	17	56	84	2	300
			SEG5	4	4	63	56	10	140